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(54) Title: TELOMERASE PROTEIN COMPONENT

(57) Abstract

Genes encoding the amino acid sequences of the protein component of *Tetrahymena* telomerase and methods for their preparation and use are disclosed. The protein component is comprised of two subunit polypeptides, and 80 kD and a 95 kD polypeptide. Methods for deducing the protein component of human telomerase and its uses are also described. The telomerase protein component may be used to develop diagnostic procedures for detection of telomerase activity in cancers, microbial diseases, and other disorders, and to produce therapeutic compounds to inhibit or enhance telomerase activity.

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Telomerase Protein ComponentBackground of the Invention

Chromosome stability is essential for cell viability. Eukaryotes have linear chromosomes and the telomeres that 5 cap the ends protect chromosomes from degradation and recombination. Loss of telomeric DNA during cell proliferation may play a role in ageing and cancer. Counter, C.M., et al. (1992) *EMBO*, 11:1921-1929.

10 Telomeric sequences are highly conserved in eukaryotes. The DNA sequence contains simple tandem repeats of specific GT-rich motifs. The exact sequences are characteristic of a particular organism; i.e., d(TTGGGG) in *Tetrahymena*, d(TTTTGGGG) in *Oxytricha* and d(TTAGGG) in humans. The number of repeats on any given 15 chromosome end varies, giving telomeres a characteristic heterogeneous or "fuzzy" appearance on Southern blots. In addition to sequence conservation, telomere function is also conserved in eukaryotes. *Tetrahymena* and human telomeres function in the yeast *Saccharomyces cerevisiae*, 20 and yeast telomeres function in other fungi. Szostak, J.W. and E.H. Blackburn (1982) *Cell*, 29:245-255. Thus the mechanisms for maintaining a stable end must share essential features in diverse eukaryotes.

25 Telomere sequences are synthesized onto chromosome ends by a highly specialized DNA polymerase called telomerase. Telomerase is a ribonucleoprotein enzyme in which both the RNA and the protein components are essential for telomerase activity. The RNA component provides the template for the telomere repeat synthesis. Blackburn, 30 E.H. (1992) *Annu. Rev. Biochem.*, 61:113-129.

Telomere replication involves the establishment of an equilibrium between telomere shortening and telomere

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lengthening. DNA replication leads to telomere shortening because DNA-template dependent DNA polymerase cannot replicate the very end of a DNA molecule. Telomerase elongates chromosomes through *de novo* sequence addition.

5 Double-stranded synthesis by DNA-template dependent DNA polymerase and primers then fill in the complementary C-rich strand.

The RNA component of telomerase has been sequenced for humans (Feng, J., et al. (1995) *Science* 269:1236-1241),
10 mice, and several mammalian species (Greider, C., unpublished data), as well as *Saccharomyces cerevisiae*, *Tetrahymena*, *Euplotes* and *Oxytricha*. See Singer and Gottschling, (1994) *Science*, 266:404-409; Lingner, et al. (1994) *Genes & Development*, 8:1984-1988; Romero, D.P. and
15 E.H. Blackburn (1994) *Cell*, 67:343-353. The protein component of a telomerase from any species has not previously been sequenced or cloned.

Summary of the Invention

Described herein are genes encoding a telomerase protein component of eukaryotic, including mammalian, origin, telomerase proteins encoded by the genes, RNA encoding the polypeptides described, and sequences that hybridize to these genes. As described herein, the genomic sequences encoding a telomerase protein component have been determined by the Applicants. Both the RNA and the protein components of telomerase are essential in the maintenance of telomeric length in chromosomes. The protein component of a telomerase can be used by itself or coupled with the RNA component in diagnostic or therapeutic methods and in assays for telomerase.

As described herein, a *Tetrahymena* gene encoding a *Tetrahymena* telomerase protein component has been isolated and sequenced. The polypeptides encoded by these genes have been shown to be an 80 kD and a 95 kD polypeptide (p80

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and p95, respectively). The polypeptides comprise a protein that, coupled with the RNA component, acts to add telomeric TTGGGG repeats to stabilize chromosomal telomere length. The present invention also provides DNA sequences 5 and portions thereof, sequences complementary to these DNA sequences, and sequences, such as probes, that hybridize to either the sense or the complementary (antisense) sequences or fragments thereof that encode the polypeptides disclosed.

10 In particular, an 80 kD and a 95 kD polypeptide which are components of *Tetrahymena* telomerase protein have been isolated and sequenced. The amino acid sequences of the 80 kD and 95 kD polypeptides of the protein component are disclosed herein, as are the DNA (nucleic acid) sequences 15 which encode the 80 kD and 95 kD proteins.

Further disclosed are nucleotide sequences encoding p80 and p95 telomerase polypeptides which are translated by most eukaryotes. These DNA sequences have been incorporated into plasmids, and the plasmids transfected 20 into vectors. Host cells comprising these vectors are provided for the production of recombinant telomerase protein component.

Both DNA sequences and polypeptide sequences that are substantially equivalent to the disclosed sequences are 25 also provided by this invention.

Also included are methods of using the DNA sequences encoding the *Tetrahymena* protein components to determine the DNA sequences encoding the protein components of other invertebrate and vertebrate species, in particular 30 mammalian species, such as the genes for human, mouse, rat, dog, cat, pig, chimpanzee, or monkey telomerase protein component.

The present work also makes available methods of determining whether a mammal, especially a human 35 individual, is likely to be affected with a disorder or

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disease in which abnormal telomerase activity is a symptom or cause. Methods of detecting telomerase expression are provided as a means of diagnosing a predisposition to the development of immortal or cancer cells in a human or in another animal. In one embodiment, DNA or RNA present in a cell or tissue sample is hybridized to a DNA or RNA probe which is complementary to all or a portion of a telomerase protein component gene. As used herein, the term "telomerase protein component gene" includes the genes whose sequence is described herein, genes which hybridize to the genes or portions thereof, and equivalent genes from other species, such as those from human, mouse, rat, dog, cat, pig, chimpanzee, monkey, or *Tetrahymena*. Detection of hybridization is an indication of a predisposition to the development of or the presence of cancer, or another disorder in which immortal cells arise.

An important feature of this invention is that the telomerase protein component can be used to screen for telomerase inhibitors which can be used to prevent telomerase expression and/or activity in cells. The protein component can be used as a basis for a method to identify and treat individuals affected by abnormal telomerase activity either within their own cells and tissues, or in foreign cells of invading parasites or disease organisms which are eukaryotes.

Therefore, the present invention provides a diagnostic tool through which inhibitors of telomerase activity can be tested and developed, and by which diseases such as cancer, or infections, such as yeast or protozoan diseases, can be diagnosed.

Another embodiment of the present invention is antibodies to a telomerase protein component, such as antibodies to one or both of the 80 kD or 95kD polypeptides, synthetic telomerase polypeptide sequences, or portions of these polypeptides. These include both

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5 polyclonal and monoclonal antibodies, such as polyclonal and monoclonal antibodies which bind either or both the 80 kD and 95 kD polypeptides of this invention. Such anti-telomerase antibodies are useful to detect telomerase activity in cells and tissues.

Further embodiments include methods of therapy and treatment involving recombinant and/or transgenic cells containing either or both of the genes for the telomerase subunits, by themselves or in combination with other genes, 10 such as a gene encoding the telomerase RNA component. Recombinant or transgenic cells producing anti-telomerase antibodies are included as well. Such methods can be applied to the treatment of disorders arising from abnormal telomerase activity or can be used to increase or trigger 15 expression of telomerase to prevent cell mortality.

Brief Description of the Figures

Figure 1 is the nucleotide sequence (SEQ ID NO:1) of the *Tetrahymena* 80 kD protein gene. The nucleotide 20 sequence is derived from genomic and cDNA clones.

Figure 2 is the amino acid sequence (SEQ ID NO:2) of the 80 kD protein deduced from the nucleotide sequence shown in Figure 1.

Figure 3 is the nucleotide sequence (SEQ ID NO:3) of 25 the *Tetrahymena* 95 kD protein gene.

Figure 4 is the amino acid sequence (SEQ ID NO:4) of the 95 kD protein deduced from the nucleotide sequence shown in Figure 3.

Figure 5 is primer set 1 consisting of 12 30 deoxyribonucleotide sequences (primers 1-12).

Figure 6 is primer set 2 consisting of 12 deoxyribonucleotide sequences (primers 13-24).

Figure 7 is primer set 3 consisting of 10 deoxyribonucleotide sequences (primers 25-34).

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Figures 8A-8B show primer set 4 consisting of 18 deoxyribonucleotide sequences (primers F1-F9 and R1-R9).

Figure 9 is primer set 5 consisting of 10 deoxyribonucleotide sequences (primers F10-F14 and R10-5 R14).

Figure 10 is the DNA sequence (SEQ ID NO:8) of the genetically-engineered p80 gene.

Figure 11 is the DNA sequence (SEQ ID NO:9) of the genetically-engineered p95 gene.

10 Detailed Description of the Invention

This invention relates to genes encoding a eukaryotic telomerase protein component, the polypeptides encoded by these genes, as well as the RNA encoding the polypeptides, complementary nucleotide sequences, and probes that 15 hybridize to sense and complementary portions of the nucleotide sequences.

Further provided are synthesized genes encoding 80 kD and 95 kD telomerase protein components, the recombinant polypeptides encoded by these genes, the RNA encoding the 20 polypeptides, the primers used to synthesize these genes, and complementary nucleotide sequences or fragments thereof.

Those skilled in the art will appreciate that many 25 different DNA sequences can encode a single protein. In addition to the genes and other nucleotide sequences described above, contemplated within this invention are DNA sequences which encode catalytically active, telomerase protein components, and nucleotide sequences that hybridize to these DNA sequences. Generally, these will hybridize 30 under moderately stringent conditions. According to the invention, the term "stringent conditions" means hybridization conditions comprising a salt concentration of 4X SSC (NaCl-citrate buffer) at 62° -66° C., and "high

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"stringent conditions" means hybridization conditions comprising a salt concentration of 0.1X SSC at 68° C. Ausubel, et al., (1994) *Current Protocols in Molecular Biology*, John Wiley & Sons, Inc.

5 Methods of using these sequences to deduce other telomerase components are described. Methods of diagnosis and treatment which use a telomerase protein component, nucleotide sequences encoding the protein component or portions thereof are also included.

10 Following is a description of the embodiments of the invention, which, together with the following examples delineating the experimental procedures, serve to explain the principles of the invention. All references to materials and methods are herein incorporated by reference.

15 The present invention also encompasses polypeptides comprising a telomerase protein component of eukaryotic origin, including the polypeptides herein described. All polypeptides which comprise a telomerase protein component and are active as a component of a telomerase are 20 encompassed by the present invention and the term telomerase protein component as used herein.

The telomerase protein component has been produced by the following method in "substantially pure" form. "Substantially pure" is defined as the minimum amino acid 25 sequence that, when combined with the telomerase RNA component, demonstrates telomerase activity.

Tetrahymena Protein Component Genes

Tetrahymena telomerase enzyme was purified using readily available chromatography matrixes. Two criteria 30 were used to follow enzyme purification. First, activity assays were performed using the standard telomerase assay (Greider, C.W. (1987) *Cell*, 51: 887-898) and 32P-dGTP incorporation was quantitated by spotting on DE-81 paper

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and determining the counts incorporated (Greider, C.W. (1987) Ph.D. Thesis, Univ. Calif. Berkeley). Second, telomerase RNA was followed by Northern blot analysis and quantitated by comparison to a titration of a known amount 5 of a synthetic telomerase RNA standard. Purification over hydroxylapatite, spermine agarose, Sepharose CL-6B sizing column, phenyl-Sepharose, DEAE agarose (or Q-Sepharose) and a 15- or 20-35% glycerol gradient, yielded highly purified telomerase fractions. Two predominant proteins of 80 and 10 95 kD were identified in the active fractions which co-purified with telomerase activity and were present in a stoichiometry similar to the telomerase RNA.

Two samples of the material purified as described above were separated on a non-denaturing gel. One lane of 15 the gel was Northern blotted to identify the position of the telomerase RNA and the other lane was cut from the native gel and run in a second dimension on an SDS PAGE gel. Most of the proteins remained near the well of the first native gel; however, both the telomerase RNA and the 20 p80 and p95 proteins ran approximately one-third of the way into the native gel at equivalent positions, indicating that p80 and p95 are components of telomerase. Beginning with over 300 L or 1.2×10^{11} cells, the active fraction in the final glycerol gradient contained over a microgram of 25 telomerase RNA. This indicated there was enough material to sequence the co-purifying polypeptides.

To determine if the p80 and p95 fraction comprises telomerase activity or is a contaminant that migrates with the same properties, telomerase was treated with 30 micrococcal nuclease. Previous experiments have shown that limited cleavage of the telomerase RNA does not completely inactivate telomerase activity. Greider, C.W. and E.H. Blackburn (1989) *Nature*, 337:331-337. Two fractions of purified telomerase were prepared for glycerol gradient

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analysis, to determine whether cleavage of the RNA would alter the mobility of the RNP in a glycerol gradient. One sample was briefly treated with micrococcal nuclease; the other was incubated with buffer only. These samples were 5 sedimented through a glycerol gradient and fractions were collected from each gradient. The activity was assayed and the protein profile determined. In the untreated fraction, activity peaked in fractions 8 and 9 along with p80 and p95. In the micrococcal nuclease-treated fraction weak 10 activity peaked in fraction 10, the peak of p80 and p95 was now also shifted to fraction 10, indicating that these proteins behave as expected for telomerase components. The sedimentation of most other proteins in the gradient 15 remained unchanged relative to the change in sedimentation of telomerase.

The partial peptide sequences from both p80 and p95 were determined. The complete amino acid sequences of the two polypeptides can be determined in the same manner. Telomerase from 344 L of *Tetrahymena* cells was purified 20 according to the procedures described above with the addition of a DEAE agarose concentration step followed by non-denaturing gel electrophoresis and SDS PAGE electrophoresis. To avoid problems associated with direct N-terminal sequencing of proteins, the excised protein 25 bands were digested with Lysylendopeptidase from *Achromobacter*. The peptide fragments were extracted from the gel and resolved on a C18 reverse phase HPLC column. Several well defined peptide peaks were subjected to successive rounds of Edman degradation on an Applied 30 Biosystems automated sequencer. From two separate preparations of telomerase, the amino acid sequence was determined for 7 peptides from p80 and for 25 peptides from p95. Degenerate oligonucleotides were designed using the *Tetrahymena* codon bias as a guide. Martindale, D.W. (1989) 35 *J. Protozol.* 36:29-34.

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Oligonucleotides were used in sets of two to obtain PCR products from either reverse transcribed RNA or from genomic DNA. Two PCR products were obtained for each protein gene. The sequence of three of the four PCR 5 products encoded peptides which had been identified by protein sequencing but were not used as primers for the PCR (Figures 2 and 4). Genomic Southern blots probed with the PCR products for either p80 or p95 proteins showed that the gene probably exists as a single copy in the *Tetrahymena* 10 genome. Northern blot analysis from actively growing cells showed a single band of about 3.0 kb for p95 and a single band of 2.5 kb for the p80 mRNA. RNA from stationary cells showed two bands when probed with the 5' portion of the 95 kD gene. This suggests alternative processing of this 15 gene.

To obtain the full length protein sequence, the cloned PCR products were used as probes for both *Tetrahymena* cDNA libraries and genomic libraries. Positive clones were obtained, subcloned, and sequenced. To deduce these 20 protein sequences, the *Tetrahymena* genetic code was used since this sequence differs from that of other eukaryotes. Prescott, D.M. (1994) *Microbiol. Rev.*, 58:233-267. Applicants have determined the sequence for the entire open 25 reading frame (ORF) for both the p80 and p95 proteins (Figure 1, SEQ ID NO:1 and Figure 3, SEQ ID NO:3, respectively). The nucleotide sequence is derived from genomic and cDNA clones; polyadenylation of the mRNA occurs near the 3' end of the reported sequence. First, Northern blot analysis of the p80 and p95 mRNAs suggests sizes of 30 approximately 2.47 and 2.9 kb. Applicants have obtained more than 2.4 and 2.8 kb of sequence for these mRNAs. Second, all reliable peptide sequence was found in the ORFs (7/7 for p80; 25/25 for p95). Third, the suggested 35 translation of the mRNAs from the first methionine codon in the longest ORF yields predicted protein products of equal

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or slightly greater molecular mass than predicted from analysis of the proteins by SDS-PAGE. Fourth, sequences outside the region translated as coding contain a higher content of A/T than coding regions, typical of *Tetrahymena* genes. Prescott, D.M. (1994) *Microbiol. Rev.*, 58:233-267. Neither of the genes has a counterpart in Genbank, EMBL, PIR and Swissprot databases.

To demonstrate that the 80 kD and 95 kD proteins are components of telomerase, polyclonal antibodies were generated against the two proteins. Synthetic peptides were synthesized that corresponded to two different regions from each protein. Two polyclonal antibodies to peptides of the 80 kD protein (designated A81 and A82) and four antibodies to peptides of the 95 kD protein (designated A83, A84, A85, and A86) showed good titre against the respective proteins.

Table 1 lists the antibodies obtained to various peptide sequences used. The peptide sequence list was obtained directly from protein sequencing of PCR products. The first peptide was derived from a preliminary sequencing trial and was determined to be incorrect after the gene was cloned. This peptide and the antibodies directed against it were subsequently used as controls. The peptide injected into rabbits to produce A85 and A86 has one error (a missing T at the penultimate position) relative to the cloned sequence; however, the antibodies against this peptide cross react with the 95 kD protein. An N-terminal C residue was added to each peptide during synthesis in order to couple the peptide to carrier protein.

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TABLE 1

Antibodies Generated Against Peptide Sequences

Antibody #	Protein Directed Against	Peptide Sequence	Amino Acid # in Sequence
79		poor (incorrect) sequence	
80		poor (incorrect) sequence	
81	80kD	(C) AEGYSDINVRG	628-
82	80kD	(C) AEGYSDINVRG	628-
83	95kD	(C) QNEFQFNNVK	610-
84	95kD	(C) QNEFQFNNVK	610-
85	95kD	(C) EFGLEPNILK	414-
86	95kD	(C) EFGLEPNILK	414-

Of these antibodies, those with the highest affinity
 15 for the 80 kD protein (A82) and the 95 kD protein (A86)
 were used to demonstrate that both the 80 kD and 95 kD
 polypeptides co-purified with telomerase activity,
 indicating that these proteins are telomerase components.
 Results of immunoprecipitation studies with the 80 kD
 20 protein are consistent and suggest the 80 kD protein is a
 functional component of telomerase.

Synthetic Protein Component Genes

To produce genes that encode the telomerase protein
 components in other eukaryotes, synthetic gene sequences
 25 were constructed in which the *Tetrahymena* genetic code was
 altered to enable correct translation and transcription in
 organisms having the genetic code which is used/translated
 in most eukaryotes; i.e., mammals such as humans. The

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genes were synthesized as gene fragments from overlapping sets of oligonucleotides (primer sets), which were then cloned into plasmids. The full-length genes were constructed by combining the fragments in the plasmids.

5 The p80 gene was constructed in the plasmid Bluescript; the p95 gene in the plasmid pSE280, although any plasmid can be used.

To express the p80 and p95 proteins, the synthesized genes were cloned into different restriction sites of the 10 pRSET and pBlueBac vectors. Transcription and translation of the genes in PRSET and pBlueBac generates the recombinant proteins in *E. coli* and baculovirus, respectively. A His-tag and cleavage site at the end of each recombinant protein facilitates the purification of 15 the proteins.

Using *E. coli* and a vector such as pRSET containing the p80 and p95 gene constructs or, alternatively, baculovirus and a vector such as pBlueBac containing the same constructs, p80 and p95 can be expressed 20 recombinantly. Thus, applicants have produced the first known bacterial strains or expression vectors which permit expression of the p80 and p95 telomerase protein components. One embodiment of this invention is the production of one or more recombinant telomerase protein 25 components in a host cell. One method comprises culturing a host cell containing the gene encoding the protein, or a homolog thereof, under conditions which permit production of the protein. In one embodiment, the method further comprises the steps of recovering quantities of protein, as 30 well as purification procedures. Skilled artisans will appreciate the various ways in which recombinant proteins of this invention can be prepared.

The recombinant proteins, or fragments thereof, are useful to detect agents that stimulate or inhibit 35 telomerase catalytic activity. They are also useful to

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produce antibodies for screening assays, such as to detect telomerase activity in tumor cells, or stimulated or inhibited production of telomerase in response to exposure to a compound.

5 Also encompassed by this invention is a telomerase polypeptide which varies in amino acid sequence from a telomerase polypeptide encoded by genomic DNA (i.e., differs from a naturally-occurring telomerase polypeptide, such as *Tetrahymena* telomerase polypeptide), without 10 affecting the ability of the polypeptide to combine with the other telomerase protein and RNA components or affect the enzymatic activity of telomerase. These variations may include additions, deletions, substitutions and other 15 alterations (e.g., modification of an amino acid residue) to the amino acid sequences.

The genes encoding the *Tetrahymena* telomerase protein component, the synthesized genes, or the primers can be used to clone the human telomerase protein component and other mammalian telomerase protein components, using known 20 methods described herein.

Two approaches can be used to clone the human telomerase protein genes with the *Tetrahymena*, synthesized, or primer sequences. These procedures are described in detail in the subsequent examples.

25 In one approach, DNA sequence hybridization is used to identify and clone a human homologue of the *Tetrahymena* protein. Human genomic DNA and mRNA blots are probed with the *Tetrahymena* gene at a series of increasing stringencies. If specific bands are identified, cDNA or 30 genomic libraries cloned into phage lambda vectors are probed at a similar stringency to identify the gene for the human homologue. Positive phage are restriction mapped, subcloned and sequenced.

A second approach is to produce a series of antibodies 35 to various regions of both the p80 and p95 proteins. The

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antibodies described above (A82 and A86) can be used. Additional antibodies can also be generated as synthetic peptides and fusion proteins and used to identify human telomerase proteins by cross-reactivity. Libraries of 5 human or other mammalian cDNAs which express a portion of the protein can be probed with the antibodies to clone the human or mammalian genes by standard molecular biology procedures. See, Sambrook, et al. (1989) *Molecular Cloning - A Laboratory Manual*, Cold Spring Harbor Press, Cold 10 Spring Harbor Laboratory, NY.

Human telomerase is an excellent target for anti-cancer therapy. The availability of the protein components for the *Tetrahymena* enzyme facilitates a thorough understanding of telomerase biochemistry and will aid in 15 the identification of specific anti-telomerase drugs.

Telomerase activity has been found in over 70 immortalized human cell lines and cancer tissues, but few human primary somatic cells or tissues. Kim, et al. (1994) *Science* 266:2011-2015. Telomere length maintenance does 20 not occur in primary human somatic cells that have a limited life span. When primary cells divide, either *in vitro* or *in vivo*, telomere length shortens. Germline cells do not show this shortening. Allsopp, et al. (1992) *PNAS* 89:10114-10118; Harley, et al. (1990) *Nature*, 337:331-337; 25 Vaziri, et al. (1993) *Amer. J. Hum. Genet.* 52:661-667. Although telomerase activity is present in immortalized human HeLa cells (Morin, G.B. (1989) *Cell* 59:521-529), telomerase has not been detected in primary fibroblast cultures. Applicants established SV40 immortalized lines 30 from primary human cells to investigate the connection between telomerase and telomere shortening. In both primary and SV40 transfected human embryonic kidney cells, telomeres shortened but telomerase was not detected as the cells were passaged. When the culture underwent crisis 35 most cell lines died; however, in the immortal clones that

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survived, telomerase activity was detected and the telomeres were short but stably maintained. Counter, et al. (1992) *EMBO J.* 11:1921-1929. Similar results were obtained with primary mouse cells in culture. Prowse, K.R. 5 and C.W. Greider (1995) *PNAS* 92:4818.

These results suggest that primary cells express little or no telomerase activity, but that following immortalization, cancer cells reactivate telomerase and maintain telomere length. In fact, telomerase activity has 10 been demonstrated in human ovarian carcinoma cells, but not in normal cervical endothelial cells. Counter, et al. (1994) *PNAS* 91:2900-2904. Telomere shortening before crisis may be lethal, but those cells that can reactivate telomerase maintain telomere length and survive crisis. 15 This model suggests that if telomerase is required for the growth of immortalized cells, telomerase inhibitors may be excellent anti-cancer drugs.

The present work provides a method by which cancers may be diagnosed prior to or during clinical manifestation 20 of symptoms by means of detecting telomerase activity in somatic cells that normally do not express telomerase. Telomerase mRNA expression in a sample of somatic cells or tissue can be detected using DNA or RNA probes; this is indicative of expression of telomerase which, in turn, is 25 an indication of immortal cancer cells since somatic cells do not normally produce telomerase. Detection of hybridization is an indication of a predisposition to cellular immortalization or cancer, or to the presence of cancer or immortal cells.

30 By hybridization, it is meant that DNA and/or RNA molecules or portions thereof are used in a hybridization analysis to detect complementary polynucleotides under conditions of moderate stringency according to methods described in Ausubel, et al., (1994) *Current Protocols in Molecular Biology*, (Suppl. 26), John Wiley & Sons, Inc.

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In one embodiment of detecting the presence of immortal cells or a predisposition to immortalization in a eukaryotic tissue sample or a sample of eukaryotic cells, nucleic acids are used as probes or primers. This 5 embodiment may comprise the steps of:

- a) obtaining a tissue sample or a sample of cells from the eukaryote; and
- b) determining the presence of telomerase in the sample, wherein if the sample demonstrates the presence of 10 telomerase, immortal cells or the predisposition to immortalization is present. The same method may be used to detect a predisposition to cancer or the presence of cancer cells or tissue.

Alternatively, the expression of mammalian telomerase 15 can be detected using polyclonal or monoclonal antibodies to the p80 or p95 polypeptide subunits, to both subunits or fragments thereof. An antibody can detect both subunits or two antibodies can be used, each of which detects a different subunit. For example, a sample of somatic or 20 tumor cells from an individual can be contacted with anti-telomerase antibodies after the sample has been processed or treated to render the telomerase (if present) available for binding to the antibody. Binding of the antibody is indicative of the presence of telomerase and, thus, an 25 indication of cellular immortalization or a predisposition to cancer, or the presence of cancer or immortal cells.

A method using antibodies to detect telomerase in a eukaryotic tissue sample or a sample of eukaryotic cells may comprise the steps of:

- 30 a) obtaining a tissue sample or a sample of cells from the eukaryote; and
- b) treating the sample to render telomerase available for binding to anti-telomerase antibodies, thereby producing a treated sample;

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- c) contacting the treated sample with anti-telomerase antibodies against (polyclonal or monoclonal) telomerase; and
- d) detecting binding of the antibodies to telomerase, 5 wherein if binding occurs, telomerase is present. It will be appreciated that antibody detection can be useful not only to detect cellular immortalization such as occurs with the development of cancer cells, and the presence of cancer or immortal cells, but also to detect the presence of 10 foreign eukaryotic cells in the cells and tissues of a multicellular organism, as described below.

The present invention also provides a means for developing drugs and pharmaceutical compounds that destroy or otherwise inactivate or interfere with the activity of 15 telomerase. A compound that inhibits or inactivates *Tetrahymena* telomerase activity can also be assessed for its effects on mammalian telomerases. The telomerase protein component, either with or without the RNA component, can be used to screen for drugs and 20 pharmaceutical compounds effective as anti-cancer and anti-microbial agents, as described below.

Further, since additional telomerase activity may have an anti-aging effect and result in restoration of cells by stabilizing telomere length, compounds can be screened for 25 their ability to stimulate or trigger telomerase activity. The protein components can also be combined with the RNA component of telomerase to produce a functional telomerase molecule which can be delivered to cells by conventional methods. Alternatively, DNA encoding a telomerase molecule 30 can be introduced into target cells by recombinant DNA methods and transformation technology. The incorporation of extra copies of functional telomerase molecules may extend the replicative life span of the host cell by stabilizing telomere length. Thus, this invention includes 35 methods for gene therapy in mammals.

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Another application of this invention is the detection of eukaryotic disease-causing organisms in somatic cells and tissues of mammals and treatment of the resulting disease. There are many fungi, protozoa, and 5 even algae that invade the cells and tissues of mammals and are the cause of various diseases. Examples of such diseases include, but are not limited to, aspergillosis, histoplasmosis, candidiasis, paracoccidioidomycosis, malaria, trichinosis, filariasis, trypanosomiasis (sleeping 10 sickness), schistosomiasis, toxoplasmosis, and leishmaniasis. These organisms require telomerase and express this enzyme as they multiply inside host cells which do not normally produce telomerase. The above-described methods to detect telomerase can be used to 15 develop early detection and diagnosis procedures for these eukaryotic microbial parasites.

An example of such a method to detect a disease caused by a eukaryotic microbial organism in a tissue sample or a sample of eukaryotic cells from an individual may comprise 20 the steps of:

- a) obtaining a tissue sample or a sample of cells from the individual; and
- b) determining the telomerase in the sample, wherein if the sample demonstrates telomerase of a eukaryotic microbe, 25 a disease caused by a eukaryotic microbial organism is present.

The telomerase in the sample can be determined by the use of nucleic acid probes or primers, including, but not limited to those described herein; or, by the use of 30 antibodies which bind to a telomerase protein component.

Furthermore, since mammalian somatic cells do not require telomerase, the use of inhibitors of and antibiotics against telomerase will provide a method of treatment for such diseases that is nontoxic or exhibits 35 little toxicity to the host. For example, most of the

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drugs used to treat diseases caused by *Trypanosoma* species can cause serious side effects and even death. Antisense RNA to the 80 kD or 95 kD protein component of *Trypanosoma* sp. telomerase or drugs against telomerase can be used to 5 inhibit telomerase and thus prevent the multiplication of species of this parasite in an individual without affecting the host's somatic cells and tissues. Included among these pharmaceuticals are antisense nucleic acids that inhibit the translation of mRNA encoding the protein 10 component of telomerase.

Compounds that inhibit or destroy telomerase activity can be formulated into pharmaceutical compositions containing a pharmaceutically acceptable carrier and/or other excipients using conventional materials and means. 15 They can be administered to an animal, either human or non-human, for therapy of a disease or condition resulting from an abnormal level of telomerase activity. Administration may be by any conventional route (parenteral, oral, inhalation, and the like) using appropriate formulations, 20 many of which are well known. The compounds can be employed in admixture with conventional excipients, such as pharmaceutically acceptable organic or inorganic carrier substances suitable for parenteral administration that do not deleteriously react with the active derivatives.

25 It will be appreciated that the actual preferred amounts of active compound in a specific case will vary according to the specific compound being utilized, the particular compositions formulated, the mode of application, the particular situs of application, and the 30 individual being treated. Dosages for a given recipient will be determined on the basis of individual characteristics, such as body size, weight, age and the type and severity of the condition being treated.

It should be noted that the formulations described 35 herein may be used for veterinary as well as human

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applications and that the term "individual" or "host" should not be construed in a limiting manner. These terms include human and nonhuman vertebrates, particularly mammals.

5 In a further aspect, the present invention provides a process for producing a recombinant product comprising:

(a) producing an expression vector which includes DNA which encodes a telomerase molecule;

(b) transfected or infecting a host cell with the vector;

10 and

(c) culturing the transfected or infected cell line to produce the encoded telomerase molecule (recombinant telomerase). The standard techniques of molecular biology can be used to prepare DNA sequences coding for the RNA and 15 protein components of telomerase, and for construction of vectors with appropriate promoters for enzyme expression in a host cell. Suitable host cell/vector systems, transfection or infection methods and culture methods are well known in the art. These systems may also be used to 20 produce antibodies to telomerase.

It will also be appreciated that the methods described above may be used to produce transgenic cells, tissues, and organisms for use in investigating the role of telomerase in eukaryotic organisms, and for therapeutic purposes.

25 Thus, this invention provides transgenic biological materials that comprise the protein components of telomerase from eukaryotes, including mammals.

The present invention will now be illustrated by the following examples, which are not intended to be limiting 30 in any way.

Example 1Purification of Telomerase

Tetrahymena thermophila were grown to a density of 4.0 x 10⁵/ml in PPYS (2% proteose peptone, 0.2% yeast extract, 5 10 μM FeCl₃), harvested by centrifugation in a GSA rotor (Sorvall), and starved for 18 h in Dryls (1.7 mM NaC₆H₅O₇, 1.2 mM NaH₂PO₄, 1.3 mM Na₂HPO₄, 2 mM CaCl₂). Starved cells were again harvested, resuspended in T2MG buffer (20 mM Tris-HCl pH 8.0, 1 mM MgCl₂, 10% glycerol, 2 mM DTT or β-10 mercaptoethanol, 0.1 mM PMSF, 2 μg/ml leupeptin, 1 μg/ml pepstatin), and lysed by addition of a final concentration of 0.2% NP-40. S-100 extract was obtained by centrifugation of lysed cells at 130,000 x g for 50 min at 4°C. All subsequent steps were done at 4°C.

15 S-100 extract derived from 1-2x10¹¹ cells (approximately 300 L of PPYS culture) was filtered coarsely and applied to ceramic HAP (AIC) equilibrated in T2MG. Telomerase was eluted with a gradient from 0.2 M K₂HPO₄ in T2MG. Fractions with peak activity were pooled, diluted 20 with 3 volumes of T2MG, and applied to Spermine agarose (Sigma) equilibrated in T2MG with 0.15 M potassium glutamate (KC₅H₈NO₄, abbreviated KG). Telomerase was eluted in T2MG with 0.65 M KG. Fractions with peak activity were pooled and loaded on a 1 L column of Sepharose CL-6B 25 (Pharmacia) equilibrated and run in T2MG with 20 mM KG and 3 mM NaN₃. Fractions with peak activity were pooled, adjusted to 0.4 M KG, and applied to Phenyl Sepharose (Pharmacia) equilibrated in T2MG with 0.4 M KG. The column was washed in T2MG, then telomerase was eluted in T2MG with 30 1% Triton X-100. Fractions with peak activity were pooled and applied to DEAE agarose (BioRad) equilibrated in T2MG. Telomerase was eluted with a gradient or a step to 0.4 M KG in T2MG. Fractions with peak activity were sometimes

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diluted with distilled water and were layered on 15- or 20-35% glycerol gradients. Gradients were centrifuged for 20 h in an SW41 rotor (Beckman). Glycerol gradient-purified telomerase was used in several experiments described in 5 this invention.

Telomerase was additionally purified prior to proteolytic digests for peptide sequencing. Glycerol gradient fractions of peak activity were pooled and applied to DEAE agarose equilibrated in T2MG. Telomerase was 10 eluted in T2MG with 0.4 M KG. Peak fractions were dialyzed against T2MG then applied to a 6% acrylamide, 50 mM Tris-acetate gel run in 50 mM Tris-acetate buffer, pH 8.0. The native gel was run for approximately 12 h at approximately 250 V. The native gel lane containing telomerase was 15 excised, soaked briefly in 2X SDS sample buffer (0.125 M Tris-HCl pH 6.8, 4% SDS, 10% β -mercaptoethanol, 20% glycerol, bromophenol blue) and sealed into the well of a denaturing 7% acrylamide gel with 0.1% agarose in mM Tris-acetate. SDS-PAGE was performed in Tris-glycine-SDS buffer 20 (25 mM Tris-HCl pH 8.3, 192 mM glycine, 0.1% SDS).

Example 2

Analytical Scale Two-Dimensional Gel Analysis

Fractions were adjusted to at least 10% glycerol and loaded on a native gel of 6% acrylamide, 50 mM Tris-acetate 25 minigel. The native gel was run in 50 mM Tris-acetate buffer, pH 8.0. The native gel lane containing telomerase was excised, soaked briefly in 2X SDS sample buffer, and sealed into the well of a denaturing 5-15% or 5-20% gradient acrylamide minigel with 0.1% agarose in 25 mM Tris-acetate. SDS-PAGE was performed in Tris-glycine-SDS 30 buffer (25 mM Tris-HCl pH 8.3, 192 mM glycine, 0.1% SDS). After electrophoresis, gels were soaked 2 x 10 min in 50% methanol and equilibrated in 5% methanol. Silver staining was performed by incubation of the gel in 0.1 mM DTT for 20

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min, 1 mg/ml silver nitrate for 20 min, and development in 0.28 M Na₂CO₃, 0.0185% formaldehyde. The staining reaction was quenched with citric acid.

Example 3

5 Proteolytic Digestion of Telomerase Subunits and Peptide Sequencing

The 80 and 95 kD subunits of telomerase were purified as described above. Preparative SDS gels containing telomerase were stained in 0.05% Coomassie brilliant blue 10 (Aldrich), 20% methanol, 0.5% acetic acid and destained in methanol-acetic acid. Polypeptides were excised from the gel after soaking 10 min in distilled water. Gel slices were crushed and soaked in 50% methanol 2 x 20 min, decanted, and dried briefly under vacuum. Proteins were 15 digested with approximately 300 ng of Achromobacter protease I in 0.1 M Tris-HCl pH 9.0, 0.01% Tween-20 for 24 h at 37°C. Peptides were separated from gel fragments by spin filtration, concentrated by Speed-Vac, and applied to a C-18 column (Vydac). Peptides were eluted with a 20 gradient of acetonitrile:isopropanol (3:1) in 0.09% trifluoroacetic acid. Peaks of absorbance at 214 nm were collected, lyophilized, and applied to a protein sequencer (ABI).

Example 4

25 Cloning of Genes for the 80 and 95 kD Telomerase Subunits

Degenerate primers were designed from peptide sequences with consideration of *Tetrahymena* codon usage frequencies. Martindale, D.W. (1989) *J. Protozool.* 36:29-34. These primers were used in multiple combinations under 30 a variety of PCR conditions. Templates for PCR included *Tetrahymena* macronuclear genomic DNA, or total or poly-A⁺ RNA (prepared as described in Ausubel, et al., (1992)

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Current Protocols in Molecular Biology, John Wiley & Sons, Inc. and Sambrook, et al., *supra*) from *Tetrahymena* grown and starved as described above). Products from PCR amplification were purified, cloned in *E. coli*, and 5 sequenced by standard protocols. PCR products were confirmed to derive from p80 or p95 gene or cDNA if the PCR product encoded additional peptide sequence not specified by the PCR primer, either as an entirely internal peptide or as sequence adjacent to that specified by the degenerate 10 PCR primer used in the reaction.

PCR products were used to screen an oligo dT-primed *Tetrahymena* cDNA library in λ gt10 (Takemasa, et al. (1989) *J. Biol. Chem.* 264:19293-19301). Only partial clones (0.8 kb or less) were obtained. Genomic libraries were 15 constructed in Bluescript KS+ (Stratagene) with EcoRI or *Cla*I digested *Tetrahymena* genomic DNA. A 3.2 kb clone was obtained that contained most of the gene for p80. A 1.1 kb clone was obtained that contained an internal region of coding sequence for the p95 gene. Fragments containing 20 other portions of the p95 gene were detected by Southern blot of EcoRI digested genomic DNA, but were drastically under-represented in the constructed libraries. To obtain the 5' end of the cDNAs for both genes, a RACE protocol was followed (Gibco # 18374-025) using poly-A+ RNA from starved 25 *Tetrahymena*. To determine the 3' end of the cDNA for p95, lambda clone sequences were compared with sequence obtained by 3' RACE. The 3' RACE was performed based on the protocol above, using oligo dT priming from the mRNA poly-A+ tail for reverse transcription, combined with priming 30 from within the known sequence of the genomic clone for PCR. To determine the 3' end of the p80 cDNA, the sequences of lambda and genomic clones were compared; the lambda clones obtained for p80 terminate at the 3' end with poly-A sequence present only as four adenine residues in

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the genomic clone. The results of 3' RACE for p80 support this region as the site of polyadenylation.

Previous determination of the nucleic acid sequence of p95 had indicated the nucleotide at position 405 to be "G" 5 and nucleotides at positions 977-979 to be "CGT". This resulted in an "R" instead of "Q" and "A", respectively, in the encoded protein.

Example 5

Generation of Antibodies to the 80 kD and 95 kD

10 Polypeptides

Synthetic peptides were synthesized that corresponded to two different regions from each protein. Peptides were purchased from Genosys Biotechnologies. These peptides were coupled to Keyhole Lymphet Hemocyanine (KLH) carrier 15 protein via an amino terminal additional cystine residue using standard protocols. Harlow, et al. (1988) *Antibodies - A Laboratory Manual*, Cold Spring Harbor Press, Cold Spring Harbor, NY. Each of the peptides coupled to KLH protein were injected into two separate rabbits using 20 standard protocols including periodic boosts with the antigen. Harlow, et al., *supra*. Sera from the rabbits was sampled every several weeks. The animal injections were generated at Hazelton Corporation. Sera from all of the rabbits after 3-4 boosts with the antigen was obtained and 25 initially tested in ELISA assays against the synthetic peptides used to inject each rabbit. Several of the crude sera specifically recognized the peptides. The antibodies were then tested against total *Tetrahymena* and purified telomerase fractions on Western blots. Two rabbits 30 immunized with one peptide had very good titre against the 80 kD protein. The antibodies from each of these rabbits are designated A81 and A82. Similarly, four rabbits immunized with two peptides had a good titre against the 95 kD protein and these antibodies are designated A83, A84,

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A85 and A86. A82 had the highest affinity for the 80 kD protein and A86 had the highest affinity for the 95 kD protein.

The antibodies were then affinity purified by binding 5 to a column with the specific peptide coupled to it. Antibodies were eluted from the column first with an acetate buffer (0.1 M NaOAc, pH 4.0) and subsequently with a glycine buffer (0.1 M glycine, pH 2.7) to remove the tighter binding antibodies. The affinity purified 10 antibodies were used for both western blots and immunoprecipitation. Western analysis with sera containing A82 and A86 antibodies showed that both the 80 and 95 kD polypeptides co-purified with telomerase activity throughout the entire column purification scheme (see 15 Example 1). The level of both the 95 and 80 kD protein paralleled the fold increase in enzyme activity at each stage in the purification, consistent with these proteins being telomerase components.

Telomerase activity was specifically immuno- 20 precipitated by the highest affinity antibody directed against the 80 kD protein (A82). Immuno-precipitation was carried out using standard techniques (Harlow, et al., *supra*). The affinity purified antibody was incubated with agarose beads (Pharmacia) coupled to protein G. After the 25 initial binding reaction the highly purified fraction from a non-peak region of the glycerol gradient (see Example 1), was incubated with the beads and telomerase was allowed to bind for 3-4 hours at 4°C. The beads were then spun at a very low speed in an eppendorf tube and the supernatant was 30 removed. The beads were washed three times in T2MG plus 0.1 M KG 0.5% NP-40 and resuspended in the same buffer. Telomerase activity was then assayed in the supernatant, the final wash and pellet fraction for each antibody. Antibody A82 showed telomerase activity in the pellet and

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the supernatant was depleted for activity. As a control, an affinity purified antibody which did not recognize either the 80 or 95 kD on Western blots (A80) was used in the immuno-precipitation. With this antibody, activity 5 remained in the supernatant as was the case with the lower affinity antibodies directed against the other 80 and 95 kD polypeptides (A83, A84, A85 and A86). These results indicate that the 80 kD polypeptide is a functional component of telomerase.

10

Example 6

Synthesis of Genes for the 80 and 95 kD Telomerase Subunits

To express the *Tetrahymena* proteins in any organism besides ciliates, the *Tetrahymena* codons that use UAA and UAG to encode glutamine (Martindale, D.W. (1989) *J. 15 Protozol.* 36:29-34) must be replaced. In most eukaryotes these codons denote "stop"; thus, their translation prevents expression of full length proteins. Because there are 44 glutamine codons in the p95 gene and 18 glutamine sites in the p80 gene that require change, these genes were 20 synthesized *de novo* rather than use site-directed mutagenesis to make each substitution. To construct the synthetic genes, it was first established which codon would be used to code for each amino acid. These codons were chosen by their frequency of use in *E. coli* and baculovirus 25 (Rohrmann, G.F. (1986) *J. Gen. Virol.* 67:1499-1513; Zhang, G. et al. (1991) *Gene* 105:61-72), two efficient systems for expressing recombinant proteins. The list of codons chosen is shown in Table 2.

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TABLE 2

Codons used for Generation of Synthetic
Telomerase p80 and p95 Proteins

	<u>Amino acids</u>	<u>Codons</u>		
5	Ala	GCT	GCC	GCA
	Arg	CGT	CGC	
	Asn	AAC		
	Asp	GAC		
10	Cys	TGT		
	Gln	CAA		
	Glu	GAG	GAA	
	Gly	GGC		
	His	CAC	CAT	
15	Ile	ATC		
	Leu	CTG		
	Lys	AAG		
	Met	ATG		
	Phe	TTC		
20	Pro	CCG		
	Ser	AGC	TCA	TCC
	Thr	ACC	ACT	
	Trp	TGG		
	Tyr	TAC		
	Val	GTT	GTG	GTC
				GTA

25 A GeneWorks (IntelliGenetics) computer program was
used to "reverse translate" the protein sequence of both
p80 and p95 using the codons in Table 2 for the genetic
code. This created a somewhat degenerate DNA sequence due
to the degeneracy of the genetic code chosen. The
30 predicted restriction map from this degenerate sequence was

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then examined to find unique restriction sites approximately every 300 bp in each gene sequence. Where necessary, restriction sites were eliminated individually by choosing a different codon to encode a particular amino 5 acid. This process was re-iterated until a unique DNA sequence was obtained that had the appropriate placement of restriction sites. The final DNA sequence including engineered restriction sites at the 5' and 3' end used for cloning are shown in Figures 10 and 11.

10 To synthesize the two genes shown in Figures 10 and 11, a set of 28 overlapping oligonucleotides were synthesized for p80 (primer sets 3 and 4, Figures 7 and 8, respectively) and a set of 34 were synthesized for p95 (primer sets 1, 2 and 3, Figures 5, 6 and 7, respectively) 15 and the genes were constructed by overlap extension PCR. Prodromou, C. and L.H. Pearl (1992) *Protein Engineering* 5:827-829; Bambot, S.B. and A.J. Russell (1993) *PCR Meths. and Apps.* 2:266-271. The oligonucleotides were purchased from Bioserve Biotechnologies (Laurel, MD). Each 20 oligonucleotide is approximately 100 nt long and is designed to overlap with its compliment to give a hybrid of 20 base pairs. Each oligonucleotide also has a phosphorothioate linkage in place of the usual phosphodiester at the 3' end of the oligonucleotide. This 25 phosphorothioate will prevent exonuclease removal of the 20 bp hybrid overlap during the initial polymerase elongation step. Skerr, A. (1992) *Nucl. Acid Res.* 20:3551-3554.

The p80 gene was constructed in two pieces by combining the first set of oligonucleotides (primer set 4, 30 Figures 8A-8B) pair-wise, then using PCR to amplify the entire region as described. The second half was constructed in a similar manner using primer set 5 (Figure 9). Each half of the gene was cloned into the plasmid Bluescript and sequenced in its entirety to be sure no new 35 mutations were introduced. The 5' half was cloned on a *Bam*

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HI-EcoRI fragment and the 3' half was cloned on a EcoRI-KpnI fragment. The full-length gene was then constructed by combining the two fragments in pBluescript (Stratagene) in the appropriate order.

5 The p95 gene was constructed in three pieces by combining each set of oligonucleotides pair-wise and then using PCR to amplify the entire region. The first fragment was constructed using primer set 1, the second fragment was constructed with primer set 2 and the third with primer set 10 3. Each of the three fragments of the gene were cloned into the plasmid pSE280 (Invitrogen) and sequenced in its entirety. The 5' fragment (Fragment and primer set 1) was cloned on a NcoI-BstBI fragment, the internal piece (Fragment and primer set 2) was on a BstBI-EcoRI fragment, 15 and the 3' fragment (Fragment and primer set 3) was cloned on an EcoRI-HindIII fragment. The full-length gene was then constructed by first combining fragments 1 and 2 in the pSE280 plasmid, and subsequently adding the 3' fragment to complete the gene.

20

Example 7

Expression and Purification of Recombinant p80 and p95 Proteins from Cells

25 The p80 and p95 proteins is expressed in *E. coli* and baculovirus by cloning the full length construct into pRSET and pBlueBac vectors respectively (Invitrogen) by methods known to those of skill in the art (See, e.g., Ausubel, *supra*; Sambrook, *supra*). These vectors allow expression and purification of the recombinant proteins. The p80 is cloned into the BamHI and HindIII sites of pRSET and 30 pBlueBac and the p95 is cloned into the NcoI and HindIII sites. Transcription and translation of these constructs generates the recombinant proteins followed by a series of 6 histidines (His-tag), separated by an EK (Enterokinase) protease cleavage site. This allows each protein to be

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purified by processing over a Ni⁺⁺ chelating column. The purified protein is removed from the His tag by digestion with the protease Enterokinase.

Example 8

5 Cloning of Human Telomerase Protein Components

Two general approaches can be taken to cloning the human genes: DNA sequence based approaches and antibody directed approaches. The first approach takes advantage of the DNA sequence of the *Tetrahymena* genes to directly 10 identify the human homologues. Those skilled in the art will recognize three different strategies that are used to clone homologues based on DNA sequence: (1) direct hybridization of human genomic or cDNA libraries with the *Tetrahymena* gene; (2) identification of conserved regions 15 in telomerase protein in other species and PCR amplification of a human gene based on these regions; and (3) systematic strategy to saturate all regions of the telomerase genes with PCR probes and identification of a human homologue using PCR to "walk" along the length of the 20 gene. All of the methodology is based on standard molecular genetic laboratory procedures (Sambrook, et al., *supra*).

In the first strategy, the *Tetrahymena* gene is used to probe human genomic DNA and mRNA blots at a series of 25 increasing stringencies. When specific bands are identified, the cDNA or genomic library can be probed at a similar stringency to identify the gene for the human homologue. Positive phage is then restriction mapped, subcloned, and sequenced.

30 The second strategy involves cloning the telomerase proteins from other ciliates first because telomerase proteins may have only limited conservation at the DNA sequence level between humans and *Tetrahymena*. Then the

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mammalian counterparts are cloned using information obtained from these cDNAs. Thus, using the cloned *Tetrahymena* genes, libraries from distantly related *Tetrahymena* or *Oxytricha* and *Euplotes* can be probed at 5 medium stringency to identify genes which cross hybridize. Since the ciliates *Oxytricha* and *Euplotes* have telomerase enzymes which are functionally similar to the *Tetrahymena* telomerase (Lingner, et al. (1994) *Genes Dev.* 8:1984-1998; Shippen-Lentz, D. and E.H. Blackburn (1990) *Science* 247: 10 546-552), it is likely that homologue proteins can be identified with this method. The genes for both the p95 and p80 homologues from both ciliates can be fully sequenced and regions of the highest degree of similarity between the different species can be identified. Three 15 conserved regions are chosen for each protein to use in Reverse transcriptase PCR-based approaches to cloning the human gene. The same approach is taken to clone the genes for both the p80 and p95 genes. Degenerate oligonucleotides encoding the conserved regions in the 20 *Tetrahymena*, *Oxytricha* and *Euplotes* telomerase proteins are synthesized using human translational codon biases. PCR is initially carried out with two of the three oligonucleotides. The 3' most oligonucleotide (oligo 1) can be complementary to the mRNA. Thus cDNA is synthesized 25 from isolated mRNA using oligo 1 as a primer. The 5' most oligo (oligo 2) can be oriented 5' to 3' in the direction opposite to oligo 1 and can be identical in sequence to the mRNA strand. This oligonucleotide is then used in a PCR step along with oligo 1 to amplify the region between oligo 30 1 and oligo 2. Finally a third primer (oligo 3) is directed against a conserved region of the protein which lies between the regions targeted by oligos 1 and 2. The sequence of the oligo will be complementary to the mRNA. The PCR product amplified with oligos 1 and 2 is 35 reamplified using oligo 2 and oligo 3. This is to assure

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that the specific products generated all have three conserved regions of the telomerase proteins. The PCR products are sequenced to identify those that contain protein homologues.

5 The third strategy is a systematic scanning approach to find regions of homology between the *Tetrahymena* and human genes, and then to amplify these regions by PCR. Using the protein sequence of the *Tetrahymena* genes as a guide, a series of primer oligonucleotides is generated
10 that encode regions of the *Tetrahymena* genes yet utilize the human codon bias in the DNA sequence. Initially, a set of primers differing in the region to which they hybridize by 10 amino acids, is generated against the 3' end of the gene. These are used in an RT PCR reaction to generate
15 cDNA. Next, a set of primers oriented from the 5' of the gene toward the 3' end are used to amplify the cDNA. All possible combinations of two PCR primers from the 5' end and 3' end can be used together to identify bands that are the size expected for the regions in the *Tetrahymena*
20 protein. If specific products are generated they are reamplified using primers that should anneal within the initial two primers. Specific products which are not generated by any primer alone are subcloned and sequenced.

Example 9

25 Antibody directed approaches to cloning human telomerase homologues

This method takes advantage of conserved epitopes on the protein surface that are recognized by antibodies. A series of antibodies are made to various regions of both
30 the p80 and p95 proteins. Antibodies such as those described in Example 5 can be used. The antigens for antibody production are generated as synthetic peptides or as fusion proteins. It is faster to produce synthetic

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peptides, since the fusion proteins do not have to be generated first; however, these peptides may not give as high a titer compared to synthetic peptides. Approximately 10-15 residues of the peptides are selected, preferably at 5 the 5' and 3' ends of the protein since these residues are likely to be unstructured and thus antigenic. In addition, computer analysis can be applied to determine the hydrophilicity and predicted secondary structure of the protein to choose regions which are likely to be 10 unstructured and near the surface of the protein. The synthetic peptide is coupled to a carrier such as KLH and used to inoculate rabbits. If the appropriate amino acids for coupling to the carrier are not present in the peptide, a linker cysteine residue is added to the N-terminus.

15 Fusion proteins are generated with the T7 polymerase system (Studier, et al. (1990) *Meth. Enzymol.*, 185:60-89) and purified for inoculation into rabbits or mice. The sera is then screened on Western blots using extracts from *E. coli* expressing the cloned protein or purified 20 fractions. The positive antibodies are tested for their ability to recognize the 95 or 80 kD proteins on Western blots and/or to specifically immunoprecipitate telomerase RNA or otherwise inhibit telomerase activity. As a control, the ability of the anti-peptide antibody to 25 precipitate telomerase RNA should be abolished when it is pre-incubated with the peptide. Because mouse and rabbit sera and monoclonal culture medium inhibit telomerase activity (L. Harrington, unpublished results), affinity purified IgG is used to test the ability of the antibodies 30 to inhibit telomerase activity.

Both polyclonal and monoclonal antibodies against *Tetrahymena* telomerase proteins can be used to identify cross-reacting telomerase proteins from human and mouse cells on Western blots. If a positive signal is found, 35 purified fractions of human telomerase is used to determine

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if the reactive band co-purifies with telomerase activity. Evidence of co-purification indicates that the cross-reacting band is a component of human telomerase. Antibodies which give the best signal are then used to 5 probe expression libraries of lambda GT11. If monoclonal antibodies are used, several different antibodies are pooled for probing the expression libraries. For polyclonal antibodies, two or three different antibodies are used on duplicate plates. Only those phage which light 10 up with both probes are considered positive. These plaques are purified and the inserts subcloned and sequenced.

Example 10

Cloning and use of the mouse homologue

The same two procedures of DNA homology or antibody 15 cross-reactivity describe above can also be used in parallel to identify the mouse telomerase protein components. Mouse telomerase clones can be useful in testing cancer therapies and for understanding the biology of mammalian telomerase. Identification of mouse 20 telomerase will also allow the use of transgenic mice to test the roles of telomere length and telomerase *in vivo*. Once either the mouse or human homologue has been identified, either clone is applied to deduce the sequence of the other organism. Sequence similarity is high between 25 human and mouse genes making it a straightforward process to obtain the clone for one with a probe from the other. Both genomic and cDNA libraries are then plated and probed at a moderate stringency to identify cross hybridizing plaques. The positive plaques are then selected, 30 restriction mapped and sequenced, to determine if the telomerase protein homologue has been cloned. Further functional analysis, such as reconstitution and gene disruption is then applied with the human and mouse clones.

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Equivalents

Those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, many equivalents to the specific embodiments of the invention 5 described specifically herein. Such equivalents are intended to be encompassed in the scope of the following claims.

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Claims

We claim:

1. A substantially pure telomerase protein component.
2. A substantially pure protein component of Claim 1,
5 which is a *Tetrahymena* telomerase protein component.
3. Isolated DNA which encodes a telomerase protein component and is identical to or substantially homologous to the nucleotide sequence of SEQ ID NO:1 or SEQ ID NO:3.
- 10 4. DNA which hybridizes under moderate stringency conditions to the DNA according to Claim 3.
5. Isolated RNA transcribed from or complementary to the DNA of Claim 3.
- 15 6. Isolated RNA transcribed from or complementary to the DNA of Claim 4.
7. A polypeptide encoded by DNA of Claim 3.
8. An isolated polypeptide comprising the amino acid sequence of SEQ ID NO:5.
9. An isolated polypeptide comprising the amino acid sequence of SEQ ID NO:7.
- 20 10. Isolated DNA which encodes a polypeptide identical to or substantially equivalent to the amino acid sequence of SEQ ID NO:2 or SEQ ID NO:4.

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- 11 An anti-telomerase antibody which binds a peptide comprising an amino acid sequence selected from the group consisting of: AEGYS DINVRG, QNEFQFNNVK and EFGLEPNILT.
- 5 12. An anti-telomerase antibody which binds all or a portion of a substantially pure telomerase protein component.
- 10 13. A method of detecting the presence of immortal cells or a predisposition to immortalization of cells in a eukaryotic tissue sample or a sample of eukaryotic cells, comprising the steps of:
 - a) obtaining a tissue sample or a sample of cells from the eukaryote; and
 - b) determining the presence of telomerase in the sample, wherein if the sample demonstrates presence of telomerase, immortal cells or the predisposition to immortalization is present.
- 15 14. A method of detecting a disease caused by a eukaryotic microbial organism in a eukaryotic tissue sample or a sample of eukaryotic cells, comprising the steps of:
 - a) obtaining a tissue sample or a sample of cells from the eukaryote; and
 - b) determining the telomerase in the sample, wherein if the sample demonstrates telomerase of a eukaryotic microbe, a disease caused by a eukaryotic microbial organism is present.
- 20 15. A method of detecting telomerase in a eukaryotic tissue sample or a sample of eukaryotic cells, comprising the steps of:
 - a) obtaining a tissue sample or a sample of cells from the eukaryote;
- 25
- 30

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b) treating the sample to render telomerase available for binding by anti-telomerase antibodies, thereby producing a treated sample;

5 c) contacting the treated sample with anti-telomerase antibodies; and

d) detecting binding of the antibodies to telomerase, wherein if binding occurs, telomerase is present.

10 16. The method of Claim 15, wherein the presence of telomerase indicates a predisposition to cancer or the presence of cancer.

17. The method of Claim 15, wherein the presence of telomerase indicates the presence of immortal cells or a predisposition to immortalization.

15 18. The method of Claim 15, wherein the presence of telomerase of a eukaryotic microbe indicates the presence of a disease caused by a eukaryotic microbial organism.

19. A method of identifying a compound that inhibits, 20 destroys, or interferes with telomerase activity in eukaryotic cells, comprising administering the compound to a *Tetrahymena* cell and measuring activity of *Tetrahymena* telomerase in the cell, wherein if the *Tetrahymena* telomerase activity is reduced, the compound is a telomerase inhibitor.

25 20. A method of identifying a compound that inhibits, destroys, or interferes with telomerase activity in mammalian, including human, cells, comprising administering the compound to eukaryotic cells expressing telomerase activity and measuring the

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activity of telomerase, wherein if the telomerase activity is reduced, said compound or compounds are identified as telomerase inhibitors.

5 21. A therapeutic or diagnostic compound comprising an inhibitor of telomerase activity in combination with a pharmaceutically acceptable carrier, diluent or excipient.

10 22. A therapeutic or diagnostic compound comprising an amino acid sequence encoded by isolated DNA according to Claim 10 in combination with a pharmaceutically acceptable carrier, diluent, or excipient.

15 23. A pharmaceutical composition comprising all or substantially all of one or both polypeptides according to SEQ ID NO:2 or SEQ ID NO:4, in combination with a pharmaceutically acceptable diluent, excipient, or carrier.

20 24. A process for the preparation of a therapeutic or diagnostic composition comprising combining an anti-telomerase compound together with a pharmaceutically acceptable excipient, diluent, or carrier.

25 25. A method for treating a disease caused by a eukaryotic microorganism in a mammal comprising administering to the mammal an amount of a telomerase inhibitor effective to inhibit telomerase activity in the microorganism.

30 26. A method of inhibiting the activity of eukaryotic microbial parasites, especially fungal and protozoan parasites, in mammals comprising administering to the mammal an amount of a telomerase inhibitor effective

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to inhibit the activity of the eukaryotic microbial parasites.

27. A method of therapeutic treatment of a human or animal suffering with a disorder associated with an abnormal level of telomerase activity comprising inhibiting the production of telomerase if said level is too high or administering telomerase if said level is too low.
- 5 28. A transgenic eukaryotic cell or organism containing the DNA sequence of Claim 3 or a sequence complementary to said sequence.
- 10 29. A transgenic prokaryotic cell containing the DNA sequence of Claim 3 or a sequence complementary to said sequence.
- 15 30. A transgenic eukaryotic cell or organism containing the nucleotide sequences SEQ ID NO:1 and SEQ ID NO:3.
31. A process for producing recombinant telomerase, comprising the steps of:
 - (a) producing an expression vector which includes DNA which encodes a telomerase molecule;
 - 20 (b) transfecting or infecting a host cell with the vector; and
 - (c) culturing the transfected or infected cell line to produce the encoded telomerase.
- 25 32. A process for producing a recombinant anti-telomerase antibody comprising:
 - (a) producing an expression vector which includes DNA which encodes an anti-telomerase antibody;

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(b) transfecting or infecting a host cell with the vector, thereby producing a transfected or infected host cell; and

5 (c) culturing the transfected or infected cell to produce the anti-telomerase antibody.

33. A DNA sequence comprising SEQ ID NO:8 or SEQ ID NO:9.

34. A synthetic telomerase protein component encoded by a DNA sequence according to Claim 33.

10 35. A DNA or RNA sequence that hybridizes to a DNA sequence according to Claim 33.

36. An expression vector comprising DNA selected from the group consisting of any of the primers 1-34, F1-F14, and R1-R14.

15 37. A host cell comprising an expression vector comprising DNA encoding a telomerase protein component or a fragment thereof.

20 38. A method for producing a telomerase protein component or a fragment thereof, comprising the step of culturing a host cell of Claim 37 under conditions which permit production of the telomerase protein component or fragment thereof.

39. A method according to Claim 38 wherein two or more telomerase protein components or fragments are produced in the same cell.

25 40. The method of Claim 38, further comprising the step of purifying the telomerase protein component or fragment.

1 aactcattta attactaatt taatcaacaa gattgataaa aagcagtaaa taaaacccaa
 61 tagatTTAAT ttagaaAGTA tcaattgaaa aatgaaATT gaaaacaACT aagcacaATA
 121 gccaaaAGCC gaaaATTGT ggtggAACT tgaattAGAG atgcaAGAAA accaaaATGA
 181 tatataAGTT agggTTAAGA ttgacgATCC taAGCAATAT ctCGTGAACG tcACTGcAGC
 241 atgtttGTTG taggaAGGTa gttACTACTa agataAAAGAT gaaAGAAGAT atATCATCAC
 301 taaAGCactt cttgaggTGG ctgAGTCTGA tcCTGAGTTC atCTGCTAGT tggAGTCTA
 361 catCCGtaAT gaACTTACA tcAGAACTAC cACTAACTAC attGTAGCAT ttGTGTTGT
 421 ccacaAGAAT actCAACCAt tcATCGAAA gtACTTCAC aAAGCAGTAC tttGCTAA
 481 tgACTTACTG gaAGTCTGTG aATTGCTATA ggttCTCTAT atTTTGTATG caACTGAAAT
 541 cAAAATTTG tatCTTGTATA ggATACTTTC ATAAGATATT CGTAAGGAAC tcACTTCCG
 601 taAGTGTtTA cAAAGATGCG tcAGAAGCAA gtttCTGAA ttCAACGAAT actAAACTTGG
 661 taAGTATTGc actGAATCTT aACGTAGAA aACAATGTC ctGTTACCTT cAGTTACCAA
 721 caAGTAAAGAAG tggattAAAG ctaAGAAAGAA gAGAAAGAG aATCTCTAA cAAACCTTA
 781 ggcaATAAAAG gaATCTGAAG ATAAGTCCAA gAGAGAAACT ggAGACATAA tGAACGTTGA
 841 agATGCAATC aAGGCTTAA aACCAGCAGT tATGAAGAAA ATAGCCAAGA gATAGAAATGC
 901 catGAAGAAA cacATGAAGG cacTAAAT tcCTAACTCT acCTTGGAAt cAAAGTACTT
 961 gACTTCAAG gATCTCTTA aGTTCTGCCA tATTTCTGAG cCTAAAGAAA gAGTCTATAA
 1021 gATCCTTGTG aAAAATACc ctaAGACCCGAGAGAAATAC aAAGCAGCCT ttGGTgATTC
 1081 tgcATCTGc ccCTTCAATC ctGAATTGGC tggAAAGCgt ATGAAGATTt AAATCTCTAA
 1141 aACATGGGAA aATGAACTCA gTGCAAAAGG caACACTGCT gAGGTTGGG ATAATTAAAT
 1201 ttCAAGCAAT taACTCCAT ATATGGCCAT gttACGTAAC ttGTCTAAcA tCTTAAAGC
 1261 cGGTGTtTCa gATACTACAC ACTCTATTGT gATCAACAAg ATTGTGAGC cCAAGGCCGT
 1321 tgAGAACTCC aAGATGTTCC ctCTTCAATT CTtTAGTGCc ATTGAAGCTG tTAATGAAGC
 1381 agTTACTAAg ggATTCAAGG cCAAGAAAGAG AGAAAATATG AATCTTAAAG gTCAAAATCGA
 1441 agCAGTAAAG gAAgTTGTG AAAAAGCCG tGAAGAGAAAG AAAGATATGG AGTTGGAGTA
 1501 aACCCAGAA ggAGAAATTG tAAAGTCAA cGAAGAAATT gGCAAGCAAT ACATTAACtC
 1561 cATTGAACtT gCAATCAAGA tagCAGTTA CAAGAATTt GATGAAATCA aAGGACACAC
 1621 tgCAATCTTc tCTGATGTT CTGGTTCTAT gAGTACCTA ATGTCAGGTG gAGCAGAA
 1681 gTATGGTTCC gTTCTGACTT gTCTCGAGTG tGcATTAGTC CTGGTTGA tGGTAAATA
 1741 acGTTGTGAA aAGTCCtCAT tCTACATCTT CAGTTACCT AGTTCTCAAT gCAATAAGT
 1801 ttACTTAGAA gTTGATCTCC CTGGAGACGA ACTCCGTCt tCTATGTAAA AACTTTGCA
 1861 agAGAAAGGA aaACTTGGTg GTGGTACTGA tttCCCTAT gAGTGCATTG ATGAATGGAC
 1921 aAAGAATAAA aTCACGTAG ACAATATCGT tATTTGTCT gATATGATGA ttGcAGAAgg
 1981 atATTCAgAT atCAATGTTA gAGGcAGTtC CATTGTTAAC AGCATCAAA AGTACAAGGA
 2041 tGAAGTAAAT CCTAACATTA AAATCTTGC AGTTGACTTA GAAGGTTACG gAAAGTGCCT
 2101 taATCTAGGT gATGAGTTCA ATGAAAACAA CTACATCAAG ATATTGCGTA tGAGCGATTc
 2161 aATCTTAAAG ttCATTTCAg CCAAGCAAGG AGGAGCAAT ATGGTcGAAG ttATCAAAA
 2221 ctTTGCCtT cAAAAAATAG gACAAAAGTG AGTTCTGA gATTCTCTA TAACAAAAAT
 2281 cTCACCCCCAC tttttGTtT tATTGCTAG CCATTATGAA ATTAAATTa TTATCTATT
 2341 attTAAGTTA CTTACATAGT ttATGTATCG CAGTCTATTa GCCTATTCAA ATGATTCTGC
 2401 aaAGAAcAAA aaAGATTAAa a

FIGURE 1

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MEIENNQAQQPKAEKLWWELELEMQENQNDIQVRVKIDDPKQYL
VNVTAAACLLQEGSYQDKDERRYIITKALLEVAESDPEFICQLAVYIRNELYIRTTTN
YIVAFCVVHKNTQPFIEKYFNKAVLLPNDLLEVCEFAQVLYIFDATEFKNLYLDRILS
QDIRKELTFRKCLQRCVRSKFSEFNEYQLGKYCTESQRKKTMFRLSVTNKQKWDQTK
KKRKENLLTKLQAIKESEDKSRETGDIMNVEDAIKALKPAVMKKIAKRQNAKKHMK
APKIPNSTLESKYLTFKDLIKFCHISEPKERVYKILGKKYPKTEEEYKAAFGDSASAP
FNPPELAGKRMKIEISKTWENELSAKGNTAEVWDNLISSNQLPYMAMLRNLSNILKAGV
SDTTHSIVINKICEPKAVENSKMPLQFFSAIEAVNEAVTKGFKAKKRENMLKGQIE
AVKEVVEKTDEEKKDMELEQTEEGEFVKVNEGIGKQYINSIELAIKIAVNKNLDEIKG
HTAIFSDVSGSMSTSMSGGAKKYGSVRTCLECALVLGLMVQRCCEKSSFYIFSSPSSQ
CNKCYLEVDLPGDELPSMQKLLQEKGLGGTDFPYECIDEWTKNTHVDNIVILSD
MMIAEGYSDINVRGSSIIVNSIKKYKDEVNPNIKIFAVDLEGYKCLNLGDEFNENNYI
KIFGMSDSILKFISAKQGGANMVEVIKNFALQKIGQK

FIGURE 2

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1 tcaatactat taattaataa ataaaaaaaaa gcaaactaca aagaaaatgt caaggcgtaa
 61 ctaaaaaaaag ccataggctc ctataggcaa taaaacaaat cttgatttg tattacaaaa
 121 tctagaagtt tacaaggcc agattgagcc ttataagacc tagtagtaat agatcaaaga
 181 ggagatctc aagctttaa agtcaaaaaa ttaagattag gatggaaact ctggcaacga
 241 tgatgatgat gaagaaaaca actcaaataa ataataagaa ttataagga gagtcatt
 301 gattaagtag caagtttaat tgataaaaaa agttggctc aaggttagaga aagattgaa
 361 tttgaacgaa gatgaaaaca aaaagaatgg actttctgaa tagcaagtga aagaagagta
 421 attaagaacg attactgaag aataggtaa gtattaaaat ttagtattt acatggacta
 481 ccagtttagat ttaaatgaga gtgtggcca tagaagacac agaagagaaa cagattatga
 541 tactaaaaa tggtttgaaa tattctatga ccaaaaaat tatgtatcaa tttacgcca
 601 ctaaaagaca tcattatgtt ggtggcttaa agattttt aataaaaaca attatgatca
 661 tcttaatgtt a gacttaaca gactagaaac tgaagccgaa ttctatgcct ttgatgattt
 721 ttcacaaaca atcaaactt ctaataattt ttactagact gtaacatac acgttaattt
 781 tgataataat ctctgtatc tcgcattgtc tagattttt ttagtactag aaagattcaa
 841 tatttgaat ataagatttt ctatatacaag aaattaaat aattttgaga aaatttggta
 901 gctacttggaa actatctcg cagttgtctt ttctatcgc cacttacaag gcattcatt
 961 acaagttcc tgcgaagcgt tctaataattt agttaactcc tcatcataaa ttagcgttaa
 1021 agatagctaa ttataggtat actcttttctc tacagactta aaatttagttt acactaaca
 1081 agtccaaagat tatttttaagt tcttataaga atccctctgt ttgactcatg taagcttagta
 1141 ggctatccca gttatgtcta ctaacgcgtt agagaaccc aatgttttac taaaaaagg
 1201 caagcatgtt aatcttaattt tagttctat ccctacttaa ttcaattttt atttctactt
 1261 tggtaatttta taacatttta aatttaggtt tggattagaa ccaaataattt tgacaaaaca
 1321 aaagcttggaa aatctacttt tgagtataaa ataatcaaaa aatcttaattt tttaagatt
 1381 aaacttttac acctacgtt cttaaagaaac ctccagaaaa cagatattaa aacaagctac
 1441 aacaatcaaa aatctcaaa acaataaaaaa tcaagaagaa actcctgaaa ctaaagatga
 1501 aactccaagg gaaagcacaat gttgtatgaa atttttgtat catcttctg aattaaccga
 1561 gcttggagat ttcagcgta acttggtaac tacccaagaa atttatgata gttgcacaa
 1621 acttttgatt agatcaacaa atttaaagaa gttcaattttaaatttgc aatcttatttgc
 1681 aaagagtaaa atggatacat tcatacatct taagaatattt tatgaaaccc taaacaatct
 1741 taaaagatgc tctgttaata tatcaaattcc tcatggaaac atttcttgc aactgacaaa
 1801 taaagattct actttttata aatttaagct gacctaacc taagaattat aacacgctaa
 1861 gtatactttt aagttagaaacg aattttatc taataacgtt aaaagtgc aaattgaatc
 1921 ttcctcatta gaaagcttag aagatattga tagtcttgc aaatcttattt cttcttgaa
 1981 aaatttacaa aatgttataa ttatcgccag tttgcttcat cccaaacata tttagaaaaa
 2041 tccttcaat aagcccaatc ttcttattttt caagcaattt gaataattga aaaatttgg
 2101 aaatgtatct atcaactgtt ttctgtatca gcatataactt aatcttattt cagaatttt
 2161 agaaaagaat aaaaaataa aagcattcat tttgaaaaga tattattttt tacaatatta
 2221 tcttgattat actaaattat taaaacact tcaatagttt cctgaattaa attaagttt
 2281 cattaaattttag caattttagaa aatttgcgtt gagtgaagta cataagtaag tatggaaaa
 2341 ccacaagcaa aagctttct atgaaccatt atgtgagttt atcaaagaat catcctaaac
 2401 cctttagcta atagattttt accaaaacac tgtaagtgtt gactcttattt aaaagatttt
 2461 agaatctata tctgagtcta agtacatca ttatggaga ttgaacccctt gttaatcttag
 2521 cagtttaattt aatctgaaa acgaagaaat ttaagaactt ctcaaagctt ggcacgaaaa
 2581 aggttttta gtaaaagcat actataaaattt ccctctatgt ttaccaactg gtacttattt
 2641 cgattacaat tcaagatagat ggtgatataat taaatattttt tttttttttt tattttat
 2701 tgaatatttc ttgcttattt atttgaataa tacatacaat agtcatttttt agtgttttga
 2761 atatattttt gttattttat tcaattttt aagtaataa ttatttttca atcattttt
 2821 aaaaaatcg

FIGURE 3

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MSRRNQKKPQAPIGNETNLDFVLQNLLEVYKSQIEHYKTQQQI
EEDLKLLKFKNQDQDGNSGNDDEENNSNKQOELLRRVNQIKQQVOLIKKVGSKVEK
DLNLNEDEKKNGLSEQQVKEEQLRTITEEQVKYQNLVFNMDFQDLNNEGGHRRHRR
ETDYDTEKWFEISHDQKNYVSIFYANQKTSYCWLLKDYFNKNNYDHLNVSINRLETEAE
FYAFDDFSQTIKLTNNSYQTVMIDVNFDNNLCILALLRFLSLERFNILNIRSSYTRN
QYNFEKIGELLETIFAVVFSHRHLOGIHLQVPCAEFQYLVNSSSQISVKDSQLQVYSF
STDLKLVDTNKVQDYFKFLQEFPRLTHVSQQAIPVSATNAVENLNVLLKKVKHANLNL
VSIPTQFNFDFYFVNQHLKLEFGLEPNILTQKLENLLSIKQSKNLKFLRLNFYTY
VAQETSRKQILKQATTIKNLKNNKNQEETPETKDETPSESTSGMKFFDHLSELTLED
FSVNLQATQEIYDSLHKLLIRSTNLKFKLSSYKYEEMEKSMDTFIDLKNIYETLNNLK
RCSVNISNPHGNISYELTNKDFSTFYFKLTLNQELQHAKYTFKQNEFQFNNVKSAKIE
SSSLESLEDIDSCKSIASCKNLQNVNIIASLLYPNNIQKNPFNKPNLFFKQFEQLK
NLENVSINCILDQHILNSISEFLEKNKKIKAFILKRYLLQYLDYTKLFKTLQQLPE
LNQVYINQOLEELTVSEVHKQVWENHKQKAFYEPCEFIKESQTLQLIDFDQNTVSD
DSIKKILESISESKYHHYRLNPSQSSSLIKSENEEIQELLKACDEKGVLVKAYYKFP
LCLPTGTYYDYNSDRW

FIGURE 4

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PRIMER SET 1

primer1 Length: 100
 1 GGGGCCATGG ATGAGCCGTC GTAACCAAAA GAAGCCGCAA GCTCCGATCG
 51 GCAACGAGAC CAACCTGGAC TTCGTTCTGC AAAACCTGGA GGTTTACAAG

primer2 Length: 100 ..
 1 CTTGGTTCTT GAACTTCAGC AGCTTCAGGT CCTCCTCCTT GATTGTTGT
 51 TGTTGGTCT TGAGTGCTC GATTTGGCTC TTGTAACCT CCAGGTTTG

primer3 Length: 99
 1 TGCTGAAGTT CAAGAACCAA GACCAAGACG GCAACAGCGG CAACGACGAC
 51 GACGACGAGG AGAACAAACAG CAACAAGCAA CAAGAGCTGC TGCCTCGT

primer4 Length: 100
 1 CGTCCTCGTT CAGGTTCAAGG TCCTTCTCAA CCTTGCTGCC AACCTTCTTG
 51 ATCAGTTGAA CTTGTTGCTT GATTTGGTTA ACACGACGCA GCAGCTCTG

primer5 Length: 100
 1 CCTGAACCTG AACGAGGACG AGAACAAAGAA GAAACGGCTG AGCGAGCAAC
 51 AAGTTAAGGA GGAGCAACTG CGTACCATCA CCGAGGAGCA AGTTAAGTAC

primer6 Length: 100
 1 TCGGTCTCGC GACGGTGACG ACGGTGGCCG CCGCTCTCGT TCAGGTCCAG
 51 TTGGTAGTCC ATGTTGAAAAA CCAGGTTTG GTACTTAACT TGCTCCTCGG

primer7 Length: 99 ..
 1 CGTCACCGTC GCGAGACCGA CTACGACACC GAGAAGTGGT TCGAGATCAG
 51 CCACGACCAA AAGAACTACG TTAGCATCTA CGCTAACCAA AAGACCAGC

primer8 Length: 100
 1 CTCGGTCTCC AGACGGTTGA TGCTAACGTT CAGGTGGTCG TAGTTGTTCT
 51 TGTTGAAGTA GTCCCTCAGC CACCAACAGT AGCTGGTCTT TTGGTTAGCG

primer9 Length: 99 ..
 1 TCAACCGTCT GGAGACCGAG GCTGAGTTCT ACGCTTCGA CGACTTCAGC
 51 CAAACCATCA AGCTGACCAA CAACAGCTAC CAAACCGTTA ACATCGACG

primer10 Length: 100
 1 GATGTTCAAGG ATGTTGAAAC GCTCCAGGCT CACCAAGGAAA CGCAGCAGAG
 51 CCAGGATACA CAGGTTGTTG TCGAAGTTGA CGTCGATGTT AACGGTTGG

primer11 Length: 99 ..
 1 CGTTTCAACA TCCTGAACAT CCGTAGCAGC TACACCCGTA ACCAATACAA
 51 CTTCGAAAAG ATCGGCGAGC TGCTGGAGAC CATCTCGCT GTTGTTC

primer12 Length: 100
 1 TTGGCTGCTG CTGTTAACCA GGTATTGAA AGCCTCACAC GGAACCTGCA
 51 GGTGGATGCC TTGCAGGTGA CGGTGGCTGA AAACAACAGC GAAGATGGTC

FIGURE 5

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PRIMER SET 2

primer13 Length: 99
 1 TGGTTAACAG CAGCAGCCAA ATCAGCGTTA AGGACAGCCA ACTGCAAGTT
 51 TACAGCTTCA GCACCGACCT GAAGCTGGTT GACACCAACA AGGTTCAAG

primer14 Length: 100
 1 CGTTGGTAGC GCTAACCGGG ATAGCTTGT GGCTCACGTG GGTCAGACGC
 51 GGGAACTCTT GCAGGAACCT GAAGTAGTCT TGAACCTTGT TGGTGTCAAC

primer15 Length: 99
 1 CCGGTTAGCG CTACCAACGC TGGTGAGAAC CTGAACGTT TCCTGAAGAA
 51 GGTTAACGCAC GCTAACCTGA ACCTGGTTAG CATCCCGACC CAATTCAAC

primer16 Length: 100 ..
 1 AGCTTTGCT TGGTCAGGAT GTTCGGCTCC AGGCCGAAC CCAGCTTCAG
 51 GTGTTGCAGG TTAACGAAGT AGAAGTCGAA GTTGAATTGG GTCGGGATGC

primer17 Length: 98
 1 CATCCTGACC AAGCAAAAGC TGGAGAACCT GCTGCTGAGC ATCAAGCAA
 51 GCAAGAACCT GAAGTTCCCTG CGTCTGAAC TCTACACCTA CGTTGCTC

primer18 Length: 100
 1 AGTCTCCTCT TGGTTCTTGT TGTTCTTCAG GTTCTTGATG GTGGTAGCTT
 51 GCTTCAGGAT TTGCTTACGG CTGGTCTCTT GAGAACGTA GGTGTAGAAG

primer19 Length: 100
 1 AACAAAGAACC AAGAGGAGAC TCCGGAGACC AAGGACGAGA CCCCAGCGA
 51 GAGCACCAGC GGCATGAAGT TCTTCGACCA CCTGAGCGAG CTGACCGAGC

primer20 Length: 100 ..
 1 GGTGGTGCT ACGGATCAGC AGCTTGTGCA GGCTGTCGTA GATCTCTTGG
 51 GTAGCTTGCA GGTTAACGCT GAAGTCCTCC AGCTCGGTCA GCTCGCTCAG

primer21 Length: 100
 1 GCTGATCCGT AGCACCACCC TGAAGAACCT CAAGCTGAGC TACAAGTACG
 51 AGATGGAGAA GAGCAAGATG GACACCTTCA TCGATCTGAA GAACATCTAC

primer22 Length: 100
 1 GTGGGTCAGC TCGTAGCTGA TGTTGCCGTG CGGGTTGCTG ATGTTAACGC
 51 TACAAACGCTT CAGGTTGTTA AGGGTCTCGT AGATGTTCTT CAGATCGATG

primer23 Length: 99
 1 TCAGCTACGA GCTGACCAAC AAGGACAGCA CCTTCTACAA GTTCAAGCTG
 51 ACCCTGAACC AAGAGCTGCA ACACGCTAAG TACACCTTCA AGCAAAACG

primer24 Length: 100
 1 ACACAGGCTG TCGATGTCCT CCAGGCTCTC CAGGCTGCTG CTCTCGATCT
 51 TAGCGCTCTT AACGTTGTTA ATTGGAATT CGTTTGCTT GAAGGTGTAC

FIGURE 6

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PRIMER SET 3

primer25 Length: 101

1 AGGACATCGA CAGCCTGTGT AAGAGCATCG CCAGCTGTAA GAACCTGCAA
 51 AACGTTAACAA TCATCGCTAG CCTGCTGTAC CCGAACAAACA TCCAAAAGAA
 101 C

primer26 Length: 100

1 TACAGTTGAT GCTAACGTTTC TCCAGGTTCT TCAGTTGCTC GAATTGCTTG
 51 AAGAACAGCA GGTTGGCTT GTTGAACGGG TTCTTTGGA TGTTGTTCGG

primer27 Length: 96

1 GAGAACGTTA GCATCAACTG TATCCTGGAC CAACACATCC TGAACAGCAT
 51 CAGCGAGTTC CTGGAGAAGA ACAAGAAGAT CAAGGCTTTC ATCCTG

primer28 Length: 100

1 GTTCAGCTCC GGCAGTTGTT GCAGGGTCTT GAACAGCTTG GTGTAGTCCA
 51 GGTAGTATTG CAGCAGGTAG TAACGCTTCA GGATGAAAGC CTTGATCTTC

primer29 Length: 101

1 AACAACTGCC GGAGCTGAAC CAAGTTTACA TCAACCAACA ACTGGAGGAG
 51 CTGACCGTTA GCGAGGTTCA CAAGCAAGTT TGGGAGAACCC ACAAGCAAAA
 101 G

primer30 Length: 100 .

1 ACGGTGTTT GGTGAAAGTC GATCAGTTGC AGGGTTTGGC TGCTCTCCTT
 51 GATGAACCTCA CACAGCGGCT CGTAGAAGGC CTTTGCTTG TGGTTCTCCC

primer31 Length: 100

1 GACTTCGACC AAAACACCGT TAGCGACGAC AGCATCAAGA AGATCCTGGA
 51 GAGCATCAGC GAGACCAAGT ACCACCACTA CCTGCGTCTG AACCCGAGCC

primer32 Length: 100

1 TAACCAGAAC GCCCTCTCG TCACAAGCCT TCAGCAGCTC TTGGATCTCC
 51 TCGTTCTCGC TCTTGATCAG GCTGCTGCTT TGGCTCGGGT TCAGACGCAG

primer33 Length: 100 .

1 CGAGAAGGGC GTTCTGGTTA AGGCTTACTA CAAGTTCCCG CTGTGTCTGC
 51 CGACCGGCAC CTACTACGAC TACAACAGCG ACCGTTGGTG AGAGCTCCAC

primer34 Length: 62

1 CCCCAAGCTT CCCGGACTA GTTCTAGAGC GGCGGCCACC GCGGTGGAGC
 51 TCTCACCAAC GG

FIGURE 7

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PRIMER SET 4

F1 Length: 82
 1 GGGCGGATCC ATGGAGATCG AGAACAAACCA AGCTCAACAA CCGAAGGCTG
 51 AGAACGCTGTG GTGGGAGCTG GAGCTGGAGA TG

F2 Length: 100
 1 CTGGTTAACG TTACCGCTGC TTGTCTGCTG CAAGAGGGCA GCTACTACCA
 51 AGACAAGGAC GAGCGTCGTT ACATCATCAC CAAGGCTCTG CTGGAGGTTG

F3 Length: 100
 1 CCGTACCAACC ACCAACTACA TCGTTGCTTT CTGTGTTGTT CACAAGAAC
 51 CCCAACCGTT CATCGAGAACAG TACTTCAACAA AGGCTGTTCT GCTGCCGAAC

F4 Length: 100
 1 CAAGAACCTG TACCTGGACC GTATCCTGAG CCAAGATATC CGTAAGGAGC
 51 TGACCTTCCG TAAGTGTCTG CAACGTTGTT TTCGTAGCAA GTTCAGCGAG

F5 Length: 100
 1 CCGTTACCTG AGCGTTACCA ACAAGCAAAA GTGGGACCAA ACCAAGAAC
 51 AGCGTAAGGA GAACCTGCTG ACCAAGCTGC AAGCTATCAA GGAGAGCGAG

F6 Length: 100
 1 GAAGCCGGCC GTTATGAAGA AGATCGCTAA CGGTCAAAAC GCTATGAAGA
 51 AGCACATGAA GGCTCCGAAG ATCCCGAACAA GCACCCCTGGA GAGCAAGTAC

F7 Length: 100
 1 CAAGATCCTG GGCAAGAAGT ACCCGAAGAC CGAGGAGGAG TACAAGGCTG
 51 CTTTCGGCGA CAGCGCTAGC GCTCCGTTCA ACCCGGAGCT GGCTGGCAAG

F8 Length: 100
 1 CTGAGGTTTG GGACAACCTG ATCAGCAGCA ACCAACTGCC GTACATGGCC
 51 ATGCTGCGTA ACCTGAGCAA CATCCTGAAG GCTGGCGTTA GCGACACCAC

F9 Length: 100
 1 CCGCTGCAAT TCTCAGCGC TATCGAGGCT GTAAACGAGG CGGTTACCAA
 51 GGGCTTCAAG GCTAAGAACG GTGAGAACAT GAACCTGAAG GGCAAATCG

R1 Length: 97
 1 GCAGCGGTAA CGTTAACCAAG GTATTGCTTC GGGTCGTCGA TCTAACACAG
 51 AACTGGATG TCGTTTGTT TCTCTGCAT CTCCAGCTCC AGCTCCC

R2 Length: 100
 1 GTAGTTGGTG GTGGTACCGA TGTACAGCTC GTTACGGATG TAAACAGCCA
 51 GTTGACAGAT GAACTCCGGG TCGCTCTCAG CAACCTCCAG CAGAGCCTTG

R3 Length: 99
 1 CGGTCCAGGT ACAGGTTCTT GAACTCGGTA GCGTCGAAGA TGTACAGAAC
 51 TTGAGCGAAC TCACAAACCT CCAGCAGGTC GTTCGGCAGC AGAACAGCC

R5 Length: 99
 1 CTTCATAACG GCCGGCTTCA GAGCCTTGAT AGCGCTCTCA ACGTTCATGA
 51 TGTCGCCGGT CTCACGCTTG CTCTTGTCTT CGCTCTCCTT GATAGCTTG

FIGURE 8A

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R6 Length: 100

1 GTACTTCTTG CCCAGGATCT TGTAAACACG TTCCCTCGGC TCGCTGATGT
51 GACAGAACTT GATCAGGTCC TTGAAGGTCA GGTACTTGCT CTCCAGGGTG

R7 Length: 99

1 CAGGTTGTCC CAAACCTCAG CGGTGTTGCC CTTAGCGCTC AGCTCGTTCT
51 CCCAGGTCTT GCTGATCTCG ATCTTCATAC GCTTGCCAGC CAGCTCCGG

R8 Length: 99

1 CGCTGAAGAA TTGCAGCGGG AACATCTTGC TGTTCTCAAC AGCCTTCGGC
51 TCACAGATCT TGTTGATAAC GATGCTGTGG GTGGTGTCCGC TAAAGCCAG

R9 Length: 101

1 CGAATTGCC CTCCTCGGTT TGCTCCAGCT CCATGTCCTT CTTCTCCTCG
51 TCGGTCTTCT CAACAACCTC CTTAACAGCC TCGATTGGC CCTTCAGGTT
101 C

FIGURE 8B

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PRIMER SET 5

F10 Length: 96
 1 CCGAGGAGGG CGAATTCTGTT AAGGTTAACG AGGGCATCGG CAAGCAATAC
 51 ATCAACAGCA TCGAGCTGGC TATCAAGATC GCTGTGAACA AGAAC

F11 Length: 99
 1 CATGAGCGGC GGCCTAAGA AGTACGGCAG CGTTCTGACC TGTCTGGAGT
 51 GTGCTCTGGT TCTGGGCTG ATGGTTAAC AACGTTGTGA GAAGAGCAG

F12 Length: 100
 1 CGGGCGACGA GCTGCGTCCG AGCATGCAAA AGCTGCTGCA AGAGAAGGGC
 51 AAGCTGGCG GCGGCACCGA CTTCCCGTAC GAGTGTATCG ATGAGTGGAC

F13 Length: 100
 1 CTACAGCGAC ATCAAACGTTG GTGGCAGCAG CATCGTTAAC AGCATCAAGA
 51 AGTACAAGGA CGAGGTTAAC CGAACATCA AAATCTTCGC TGTTGACCTG

F14 Length: 85
 1 CAAAATCTTC GGCATGAGCG ACAGCATCCT GAAGTCATC AGCGCTAACG
 51 AAGGCGGCAC TAACATGGTG GAGGTGATCA AGAAC

R10 Length: 100
 1 CTTAGCGCCG CCGCTCATGC TGGTGCTCAT GCTGCCGCTG ACGTCGCTGA
 51 AGATAGCGGT GTGGCCCTTG ATCTCGTCCA GGTTCTTGTT CACAGCGATC

R11 Length: 100
 1 GACGCAGCTC GTCGCCCGGC AGGTCAACCT CCAGGTAACA CTTGTTACAT
 51 TGGCTGCTCG GGCTGCTGAA GATGTAGAAG CTGCTCTTCT CACAACGTTG

R12 Length: 100
 1 GAACGTTGAT GTCGCTGTAG CCCTCAGCGA TCATCATGTC GCTCAGGATA
 51 ACGATGTTGT CAACGTGGGT CTTGTTCTTG GTCCACTCAT CGATACACTC

R13 Length: 98
 1 CGCTCATGCC GAAGATTGAT ATGAGTTGT TCTCGTTGAA CTCGTCGCC
 51 AGGTTCAAGAC ACTTGCCGTA GCCCTCCAGG TCAACAGCGA AGATTG

R14 Length: 85
 1 GGGCGGTACC AAGCTTTCTA GACTAGTCTG CAGTCACCTT TGGCCGATCT
 51 TTTGCAGAGC GAAGTTCTTG ATCACCTCCA CCATG

FIGURE 9

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GGGCGGATCCATGGAGATCGAGAACAAACCAAGCTAACAAACCGAAGGCTGAGAAGCTGTGG
TGGGAGCTGGAGCTGGAGATGCAAGAGAACCAAAACGACATCCAAGTTCGTGTTAAGATCG
ACGACCCGAAGCAATACCTGGTTAACGTTACCGCTGCTGTCTGCTGCAAGAGGGCAGCTA
CTACCAAGACAACGGACGAGCGCTCGTTACATCATCACCAAGGCTCTGCTGGAGGTTGCTGAG
AGCGACCCGGAGTTCATCTGTCAACTGGCTGTTACATCCGTAACCGAGCTGTACATCCGTA
CCACCACCAACTACATCGTGTCTGTGTTACAAAGAACACCCAAACCGTTACATCGA
GAAGTACTCAACAAGGCTGTTCTGCTGCCAACGACCTGCTGGAGGTTGTGAGTTGCT
CAAGTTCTGTACATCTCGACGCTACCGAGTTAACGAACTGTACCTGGACCGTATCTGA
GCCAAGATATCGTAAGGAGCTGACCTCCGTAAGTGTCTGCAACGTTGTGTTGCTAGCAA
GTTCAAGCGAGTTAACGAGTACCAACTGGCAAGTACTGTACCGAGAGCCAACGTAAGAAG
ACCATGTTCCGTTACCTGAGCCTAACCAACAAGCAAAGTGGGACCAACCAAGAAGAAC
GTAAGGAGAACCTGCTGACCAAGCTGCAAGCTATCAAGGAGAGGGAGAACAGCAAGCG
TGAGACCCGGCAGACATCATCAACGTTGAGGAGCGTATAAGGCTCTGAGGCCGGCTTATG
AAGAAGATCGCTAACCGTAAACCGCTATGAAGAACGACATGAAGGCTCCGAAGATCCCGA
ACAGCACCCCTGGAGAGCAAGTACCTGACCTTAAGGACCTGATCAAGTTCTGTCACATCAG
CGAGCCGAAGGAACGTGTTACAAGATCCTGGCAAGAAGTACCCGAAGACCGAGGAGGAG
TACAAGGCTGTTCCGGCAGCGCTAGCGCTCCGTTAACCCGGAGCTGGCTGGCAAGC
GTATGAAGATCGAGATCAGCAAGACCTGGGAGAACGAGCTGAGCGTAAAGGCAACACCGC
TGAGGTTGGGACAACCTGATCAGCAGCAACCAACTGCCGTACATGGCATGCTGCGTAAC
CTGAGCAACATCCTGAAGGCTGGCGTTAGCGACACCCACACGATCGTTATCAACAAGA
TCTGTGAGCGAAGGCTGTTGAGAACAGCAAGATGTTCCCGCTGCAATTCTTCAGGCTAT
CGAGGCTGTTAACGAGCGGTTACCAAGGCTTCAAGGCTAAGAAGCGTGAGAACATGAAC
CTGAAGGGCAAATCGAGGCTGTTAGGAGGTTGAGAACGAGCAGGAGGAGAACAGG
ACATGGAGCTGGAGCAAACCGAGGGAGGGCAATTGTTAACGTTAACGAGGGCATGGCAA
GCAATAACATCAACAGCATCGAGCTGGCTATCAAGATCGCTGTGAAACAAGAACCTGGACGAG
ATCAAGGGCACAACCGCTATCTCAGCGACGTAGCGCAGCATGAGCACCGCATGAGCG
GCGGCCATAAGAAGTACGGCAGCGCTGTTACCTGTCAGGAGTGTGCTCTGGTTCTGGCCT
GATGGTTAACGCAACGTTGAGAACAGCAGCTTACATCTTCAGCAGGCCGAGCAGCCAA
TGTAACAAGTGTACCTGGAGGTTGACCTGGCGGAGCAGGCTGCGTCCGAGCATGCAA
AGCTGCTGCAAGAGAACGGCAAGCTGGCGGCGACCGACTTCCGTAAGGAGTGTATCGA
TGAGTGGACCAAGAACAAAGACCCACGTTGACAACATCGTTATCTGAGCGACATGATGATC
GCTGAGGGCTACAGCGACATCAACGTTCTGGCAGCAGCATCGTTAACAGCATCAAGAAGT
ACAAGGACGAGGTTAACCCGAACATCAAATCTCGCTGTTGACCTGGAGGGCTACGGCAA
GTGTCTGAAACCTGGCGACCGAGTTAACGAGAACAAACTACATCAAATCTCGCATGAGC
GACAGCATCCTGAAGGTTACATCAGCGCTAACGAAAGCGGCGCTAACATGGTGGAGGTGATCA
AGAACTTCGCTCTGAAAAGATCGGCCAAAGTGAACGACTAGTCTAGAAAGCTTGG
ACCGCCC

FIGURE 10

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GGGGCCATGGATGACCGTCGTAACCAAAAGAACGCGCAAGCTCGATCGGCAACGAGACC
 AACCTGGACTTCGTTCTGCAAAACCTGGAGGTTACAAGAGCCAATCGAGCACTACAAGA
 CCCAACAAACAACAAATCAAGGAGGAGGACCTGAAGCTGCTGAAGTTCAAGAACCAAGACCA
 AGACGGCAACAGCGGCAACGACGACGAGGAGAACAAAGCAACAAGCAACAAGAG
 CTGCTGCGTCGTTAACCAAATCAAGCAACAAGTCAACTGATCAAGAACGGTTGGCAGCA
 AGGTTGAGAAGGAGCCTGAACCTGAACCGAGGAGAACAAAGAACCGCCCTGAGCGAGCA
 ACAAGTTAACGAGGAGCAACTGCGTACCATCAGGAGGAGAACGTTAACGTTAACCAACCTG
 GTTTCAACATGGACTACCAACTGGACCTGAACGAGGAGCGGGCCACCGTCACCGTC
 GCGAGACCGACTACGACACCGAGAACGTGGTCTGAGATCAGCCACGACCAAAGAACACTACGT
 TAGCATCTACGCTAACCAAAGACAGCTACTGTTGGTGGCTGAAGGACTACTTCAACAAG
 AACAACTACGACCACCTGAACGTTAGCATCAACCGTCTGGAGAACCGAGGCTGAGTTCTACG
 CTTTCGACGACTTCAGCCAAACCATCAAGCTGACCAACAACAGCTACCAAACCGTTAACAT
 CGACGTCAACTTCGACAACAAACCTGTATCCTGGCTCTGCTGCGTTCTGCTGAGCCTG
 GAGCGTTAACATCCTGAACATCCCTAGCAGTACACCGTACCAAATACAACCTCGAAA
 AGATCGGGAGCTGCTGGAGACCATCTCGCTGTTTCAAGCCACCGTCACCTGCAAGG
 CATCCACCTGCAAGTCCGCTGAGGCTTCCAATACCTGGTTAACAGCAGCAGCCAAATC
 AGCGTTAAGGACAGCCAACCTGAACGTTACAGCTTACGACCCACCTGAAGCTGGTTACA
 CCAACAAAGTTCAAGACTACTTCAAGTTCTGCAAGAGTTCCCGCTCTGACCCACGTGAG
 CCAACAAAGCTATCCGGTAGCGCTACCAACGCTGTGAGAACCTGAACGTTCTGCTGAG
 AAGGTTAACGACGCTAACCTGAACCTGGTAGCATCCGACCCATTCAACCTCGACTTCT
 ACTTCGTTAACCTGCAACACCTGAAGGCTGGAGCTTCGGCCTGGAGCCGAACATCCGTACCAA
 GCAAAGCTGGAGAACCTGCTGCTGAGCATCAAGCAAGAACCTGAAGTTCTGCGT
 CTGAACCTCTACACCTACGTTCTCAAGAGAACGACCGCTAACCAAATCCTGAAGCAAGCTA
 CCACCATCAAGAACCTGAAGAACACAAGAACCAAGAGGAGACTCCGGAGACCAAGGACGA
 GACCCCGAGCAGAGAACCGAGCCAGGGCATGAAGTTCTGACCCACTGAGCGAGCTGACCGAG
 CTGGAGGACTTCAGCGTTAACCTGCAAGCTACCAAGAGATCTACGACAGCCTGACAAGC
 TGCTGATCCGTAGCACCAACCTGAAGAACGTTCAAGCTGAGCTACAAGTACGAGATGGAGAA
 GAGCAAGATGGACACCTTCATCGATCTGAAGAACATCTACGAGACCCCTGAACAACCTGAAG
 CGTTGTAGCGTTAACATCAGCAACCGCAGCGAACATCAGCTACGAGCTGACCAACAAGG
 ACAGCACCTCTACAGTTCAAGCTGACCCCTGAACCAAGAGCTGCAACACGCTAAGTACAC
 CTTCAAGCAAACGAATTCCAATTCAACACGTTAACAGCGCTAACGAGCTGAGAGCAGCAGC
 CTGGAGAGCCTGGAGGACATCGACAGCCTGTAAGAGCATGCCAGCTGTAAGAACCTGC
 AAAACGTTAACATCATCGCTAGCCTGCTGTACCCGAACAACATCCAAAAGAACCGTTCAA
 CAAGCCGAACCTGCTGTTCTCAAGCAATTGAGCAACTGAAGAACCTGGAGAACGTTAGC
 ATCAACTGTATCTGGACCAACACATCCTGAACAGCATCAGCGAGTTCTGGAGAACAA
 AGAAGATCAAGGCTTCATCTGAAGCGTTACTACCTGCTGCAATAACTACCTGGACTACAC
 CAAGCTGTTCAAGACCCCTGAACAAACTGCCGGAGCTGAACCAAGTTACATCAACCAACAA
 CTGGAGGAGCTGACCGTTAGCGAGGTTACAGCAAGGTTGGAGAACCAAGCAGCAAAGG
 CCTTCTACGAGCCGCTGCTGAGGTTACAGGAGAGCAGCCAAACCGCTGCAACTGATCGA
 CTTCGACCAAAACACCGTTAGCGACGACAGCATCAAGAACGATCTGGAGAGCATCAGCGAG
 AGCAAGTACCAACCAACTACCTGCGTCTGAACCCGAGCCAAAGCAGCAGCCTGATCAAGAGCG
 AGAACCGAGGAGATCCAAGAGCTGCTGAAGGCTTGTGACGAGAACGGCGTTCTGGTTAAGGC
 TTACTACAAGTTCCCGCTGTGCTGCCGACCGCACCTACTACGACTACAACAGCGACCGT
 TGGTAGAGACTCCACCGCGGTGGCGCCGCTCTAGAAACTAGTCCCGGAACGTTGGGG

FIGURE 11

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